Margaret Davidson
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ECONOMIC ZOOLOGY

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ECONOMIC ZOOLOGY

AN INTRODUCTORY TEXT-BOOK IN ZOOLOGY

WITH SPECIAL REFERENCE TO ITS APPLICATIONS IN AGRICULTURE, COMMERCE, AND MEDICINE

BY

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PREFACE

THE immense progress in recent years in the application of scientific knowledge concerning animals to the affairs of everyday life, the great extent to which animals and animal products enter into commerce, and the very vital relation that is now known to exist between various forms of life and the diseases affecting man and the domestic animals, seem to warrant a general text in zoology in which these phases of the subject are given more emphasis than has been the practice. Such a viewpoint has, moreover, the advantage of awaking an interest in the subject which, from a purely educational standpoint, is not to be overlooked. Interest is one of the prime factors in concentrated, effective study, and to know that the subject studied bears in an important way on life and prospective duties is no small element in successful study. It is the writer's belief that such forms as the parasitic worms, trichina, earthworm, oyster, crayfish, grasshopper, mosquito, fish, or bird lose none of their scientific interest or value as disciplinary objects of study when their importance to human life is considered. On the contrary, his own experience leads him to believe that this viewpoint stimulates to more careful and effective study.

This book, however, is not intended merely as a text-book for the school or college student, but it is hoped that it may be of service to that ever-increasing body of citizens who wish to familiarize themselves with the general principles and the present status of knowledge regarding the animal kingdom.

In a subject that is undergoing rapid change and constant addition, it is impossible that a text-book should present the latest word on every topic. The effort here has been rather to show

the established facts and avoid in the main the unsettled or debatable problems, or to present them in such manner as to enable the student to understand and estimate the discussions on such questions in current literature.

While the writer is indebted to many sources for material worked into this volume, and while it is impossible to enumerate these in detail, it seems fair to mention in particular the publications of the Bureaus of Entomology, Animal Industry, Fisheries, and the Biological Survey of the United States Government, which have been most important sources of information. Many of the illustrations are reproduced here by the kind permission of the Officers of these Bureaus.

I have also been favored with drawings for reproduction from a number of my students, those by Miss Detmers and Messrs. Sim and Shira deserving special mention. My son has assisted me to several photographs.

I desire to acknowledge the kind assistance of Professors Herms, Hine, Jackson, and Walton, and of my wife, who have read certain chapters, and especially the helpful criticisms and suggestions of my associate, Professor F. L. Landacre, who has read the entire manuscript, has tested portions of it in his classroom, and given me the benefit of his rich experience as a teacher. I am also much indebted to Professor E. L. Rice for a critical reading of the proof, and to the publishers for their liberality in the provision of illustrations.

HERBERT OSBORN.

Ohio State University,
June 1, 1908.

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CHAPTER I

INTRODUCTION

BEFORE taking up the detailed discussion of our subject, it may be in place to consider briefly the aims in view, and methods by which we undertake to secure a knowledge of our subject.

Zoology deals with the subject of animal life, and considered in the broad sense this must be interpreted as including whatever pertains to the life of the animal. We are not to consider merely the structure, or the classification, or the habit of animals, but, with all these phases of study, we are to consider the relation of the different forms of animals to each other, and also their relation to mankind, since these have in a great measure affected the course of development and determined the conditions of existence of the different kinds of animals. It is evident that but a small part of this subject can be covered in an elementary course, but it should also be remembered that whatever observations one has been able to make during his lifetime are to be considered a part of one's available material to be systematically arranged and correlated with what may be learned of other forms or other phases of life in the animals studied in a definite course.

While we doubtless realize, if we stop to think a little, that animal life is a most abundant feature on the earth, it is perhaps hardly possible to conceive of the immense variety and extent of living organisms which have been, or are at present, distributed over the earth.

While there is a fundamental similarity between plants and animals, a close agreement in the basis of life activities, there is no question as to where we place the majority of the forms with which we are familiar.

We never doubt as to the position of the horse and the grain on which it feeds or think of confusing the more characteristic structures or activities of such a form as a bird and the tree in which it may nest.

While, therefore, we should fully recognize the points of unity and remember that among some of the simplest it is difficult to distinguish plant from animal organisms, we need not be particularly concerned as to the questions involved in separating them.

Animal life in some form occupies practically every corner of the earth; occurring in the oceans, even at a great depth, and on land even in the most unfavorable conditions of dryness and of altitude, so that from the most favored conditions of warmth and moisture to the most unfavorable conditions of heat and cold some form of life will almost certainly be found. That animals existed in great abundance in the past, is clearly shown in the fossil forms that are found in different rock strata, running back as far as the oldest stratified rocks that are known. This branch forms a distinct field, called **Paleontology.**

While we know but little as to conditions in which life originated, we must assume that it arose primarily from inorganic matter, but so far as known at the present time, living forms arise only as descendants of parent forms, and we can only infer that this process has been continued from a very remote period. It is apparent, however, that in the lapse of time, animal life has changed and that while existing species must have descended from those occurring in the past, there has been some process of modification, so that the ancestral forms, if traced back far enough, would present different characters. Our present concern, of course, is more directly with forms of life existing at the present time, but it will be of interest to inquire how these forms are related to those forms which have preceded them and the evidences of which are preserved for us in fossils. The number of species living at present is doubtless as great, if not greater, than at any time in earlier history, and while many kinds have become extinct, their numbers have been more than made good by new forms that have been arising.

Classification. — The grouping of animals into divisions in which similar kinds are placed together or classified has two objects in view: first, as a matter of convenience to bring together those which are similar and to designate them by some common name, so that they may be referred to in general terms. The group of birds, for instance, under this general name carries with it an animal with feathers and wings that are characters common to all kinds of birds. The other purpose, and more fundamental one, is to indicate the natural affinity of kinds so associated, or in a deeper sense to associate those that have had common origin or ancestry. Birds, again, for example, although occurring in thousands of different kinds at present, may be assumed to have arisen from some generalized ancestral bird, unlike any occurring at present, but which possessed a covering of feathers, possibly had wings, and possessed other structures which are common to all birds.

We arrange all animals included under the animal kingdom into **branches** (**phyla**), divide these again into **classes**, and classes into **orders**, and orders into **families**, families into **genera**, and genera into **species**, the species being recognized as the unit in nature, or including individuals of such similar features as not to be easily separable, or so similar as to readily interbreed.

Closely related species are grouped into genera, so that a genus is simply an arbitrary assemblage of species. There may be any number from one to one hundred or more, and nearly related genera are again assembled in families, families into orders, orders into classes, classes into branches, which are finally combined in the animal kingdom as a whole. When we speak, therefore, of a general group, as birds, fishes, mollusks, etc., we should have in mind the fact that these general groups include an immense number of kinds of animals and that each is divided into orders, families, genera, and species according to one general plan. In common usage, the name of the animal stated in scientific terms consists of the genus and species name, the genus always being given first, as, for instance, **Canis familiaris**, the dog, while another species of the genus, the coyote, for example, would be **Canis latrans**.

While no one can expect to become familiar with the names of all these different kinds of animals or even minor divisions of them, the names of the principal groups, and such forms of animals as are dealt with more particularly, will gradually become familiar, and without any effort at memorizing one should come in time to recognize them just as he would the names of familiar friends. No attempt should be made to learn the name of a group or an animal unless it can be associated with a definite character or fact covering such a group or animal.

Aside from the relation of species, members of a common genus, or common family, we must stop to consider also the relation existing between the different species which occupy the same locality or which in their habits are in some way dependent upon each other. We know that certain animals depend for their food upon catching and devouring other animals and are in this way dependent upon them, while in other cases, as in parasitic forms, one animal serves as host for another and is preyed upon in such a manner that it may not suffer very great immediate loss, but in time or with an excessive number of parasitic forms may be weakened or even killed. We find that in thousands of ways these dependencies of one animal upon another enter into their actions and control their ability to thrive and multiply, and further, all animal life, in the end, is dependent upon the growth of plant life, since animals are incapable of transforming inorganic matter or substance directly into organic matter. Plant life, on the other hand, feeds in general upon inorganic matter and serves to change it to organic matter, so that in the last analysis we may say that all animal life is dependent upon plant life. The cycle of changes which may occur, however, between any particular animal and the plant life which serves it as food would be too intricate to follow, as it may feed upon some weaker form of animal, and this again upon other animal forms. in an extended series, until at last some forms are reached which are dependent upon plant life.

If we consider man as simply one species of animal, and that like other animals he is dependent upon other forms of life for

subsistence, it is easy to understand that nearly every form of animal will possess some important interest to the human species, and that an exhaustive study of an animal may eventually result in important knowledge as to its relation to human life. Inas much as **Economic Zoology** is simply an application of our knowledge of animals which affect human interests, it is easy to see that almost any phase of the study will have some bearing on the problems that concern us. Economic zoology, if studied thoroughly, must of necessity be based on accurate knowledge regarding structure, relations, habits, and activities of animals, so that it involves a study of the whole animal and all that can be learned regarding its activities. Some of the facts which concern us most directly are regarding those animals which we use for food, such domesticated animals as cattle, swine, etc.; those which are taken for game, many kinds which are caught from seas or rivers, as fish, turtles, frogs, oysters, etc.; those which furnish clothing material, such as wool, furs, and silk; those which are detrimental in attacks on our crops or upon our domesticated animals; or those which may attack us directly or which are annoying or injurious or which in some instances may be of some importance as carriers or transmitters of disease, as in malaria or yellow fever; or again, those which invade our dwellings and feed upon our stored foods, clothes, carpets, etc.; those which are poisonous and whose stings or bites are both annoying and dangerous and those which act as scavengers, disposing of organic débris. Many of those which furnish food supplies or clothing material enter very largely into commerce, and we need only mention such terms as beef, milk, butter, fish, oysters, pearls, pearl buttons, ivory, hair, furs, sealskin, feathers, ostrich plumes, horn, tortoise shell, bone, honey, beeswax, silk, lac, cochineal dye, etc., to suggest some of our greatest industries and most important articles of commerce.

Then again, a knowledge of animal life may be of great importance to us as illustrating certain fundamental biological principles which should be understood as being effective in human society as among the lower groups of animals. Such general prin-

ciples as are exhibited in parasitic animals and sedentary animals, or as may be learned in the complex relations among the gregarious and social species, may teach us most valuable lessons as to principles of human society or as to the consequences which must certainly follow the adoption of certain modes of life.

Animal Functions

There are certain activities which are common to all kinds of animals, and a recognition of which will help greatly in understanding the definite structure or organs which are concerned in the life of animals. All animals must obtain nutrition in one form or another, that is, all animals must have food, and this implies some method of taking in food material and that this be appropriated by the tissues of the organism. In its simplest condition, this may be simply inclusion of organic matter or substance which can be utilized by the protoplasmic content of cells. Usually, however, some distinct process or change takes place before nutrient material is available for special tissues. This may consist simply of digestion or the results of digestion being absorbed into or assimilated by cells that surround it, but in animals of larger size there must be some method of distribution, and this results in the systems of circulation and special forms of assimilation. **Nutrition**, as a general factor, may include, then, such processes as **prehension**, or the collecting of food; **ingestion**, or the swallowing of food; **digestion**, or the change to a soluble or assimilable condition for absorption; **circulation,** or distribution and assimilation. Connected with nutrition also, or following metabolism connected with tissue activity, is the resulting waste or nitrogenous products which must be eliminated from the tissues, and which processes are known in general as **excretion**. These are eliminated by some form of kidney.

Closely connected with nutrition also is **respiration**, which supplies one essential element (oxygen) in the activity of the animal, which combines with carbon in a process similar to combustion,

thus giving rise to carbon dioxide. Another very general group of activities may be considered under the head of **locomotion,** All animals for part of their life or in some parts of the body have the ability to move, and this is based upon the property of contractility residing in the protoplasm or, for all the higher animals, in special tissues, as the muscle. Locomotion, however, is connected with a very great variety of structures, among which may be mentioned pseudopodia, cilia, flagella of protozoa; the parapodia and setæ in worms; the swimmerets and legs in crustaceans; legs and wings in insects, and fins, legs, paddles, wings, etc., in vertebrates.

Another distinct series of activities is represented in the sensibility or sensation possessed by different animals, or simply a condition which may be represented by the **irritability** in the single cell, or a response to contact or stimuli of different kinds by contracting or changing form, or in movements of the cilia or other surface structures. In more specialized forms this is represented by more special senses, as touch, taste, smell, hearing, and sight, for which numerous complex organs of sense are developed, the most extreme of which are represented in the eyes and ears of animals, which are most perfectly endowed with sensitive organs. We have, then, three great groups of activities in nutrition, locomotion, and sensation which are essential to the life of the individual and which are found in some form in every kind of animal organism. It is essential, however, to the perpetuity of every kind of animal that it should be able to reproduce its kind, and this gives us a fourth general function — that of **reproduction.** This is presented in some form in all kinds of animals, but there are a number of different methods of reproduction and processes by which the number of individuals may be multiplied and hence the perpetuity of the species assured. The simplest form is that of division of an individual into two, and successive divisions of the resulting individuals. This is the most common method amongst the single-celled animals. Amongst the higher forms there is usually the development of two sexes

or individuals producing germinal elements of a different character and the union of which is essential to the formation of a new individual. Special modes of reproduction will be noted in the different groups as they are considered.

The activities mentioned are those which concern the individual or the species, but if we consider the actual existence of the animal in life, we must recognize those activities which are related to other organisms or its surroundings. Every animal is dependent for its existence upon the presence of certain conditions of environment, including air, water, food, etc. Often a very complicated combination of conditions is established by forms which have succeeded in maintaining their existence, and a study of these relationships constitutes a most important phase of Zoology, **ecology**. This perhaps can be seen by an example, such as, for instance, the rabbit. This is a plant feeder, and by itself the main condition necessary for its existence is an abundance of plant food. The rabbit, however, multiplies with great rapidity — a single pair being able to produce within a year probably as many as several hundred of progeny. It would be but a matter of a short time, if their increase were unchecked, until all available food in any given locality would be exhausted. In their native conditions, however, rabbits are fed upon by foxes, wolves, weasels, skunks and other carnivorous animals which serve to keep their numbers reduced. Taking one of these carnivorous forms, we can see that successful existence for the fox would lie in the supply of rabbits as food material, but the increase of foxes would be largely limited by the supply of rabbit food, and if only these two forms existed, we would expect a balance to be established. Again, however, another factor is introduced, as the wolf, and there would be a contest between the two forms, both tending to further reduce the stock of rabbits, and the basis of supply for each of these species would result in the further limitation of the numbers or the driving out of the surplus individuals of one or the other species. This would be complicated still further, of course, by the inclusion of other forms,

like weasels, skunks, etc., but, on the other hand, is complicated further by the fact that these forms are not dependent upon rabbits only, but that other carnivorous or herbivorous animals may be used as food, so that birds, chickens, squirrels, mice, and a considerable variety of species would be included in the combination. It is easily apparent that a full knowledge of all the factors which may enter into the life of one kind of animal is extremely difficult to secure, but that without some conception of these relations our knowledge of animal life would be very incomplete; that is, our knowledge of structure, or morphology, and activities, or physiology, must be supplemented by the knowledge of relationships to other organisms, or ecology, if we would properly appreciate the problems for any kind of animal.

The relations of this kind pass directly into relations affecting the human species, and with even this same example we can see that the kind of animals presented becomes of importance for the use of our own interests. Rabbits, for example, may be used for human food, or, on the other hand, in their attacks on our apple trees, shrubbery, etc., may cause us extensive damage, so that it is to our interest that predatory forms should feed upon them to such an extent as to reduce their number as much as possible; but these predatory forms may affect us by catching chickens or domestic animals which are of value to us, so that the relation for a given animal may have different aspects to mankind; that is, its economic status may vary in different localities or at different times, or from day to day, according to the character of food it may eat. With this very general outline of our subject and the purpose in view in our study, we may take up a consideration of the different animals in a systematic order, including in the different groups such discussion of a general nature as may be strikingly illustrated in particular groups.

CHAPTER II

PROTOZOA

THE Protozoa are the simplest forms of animals and are very distinctly set off from the other groups by the fact that they are composed of but a single cell. This might appear to give them much greater simplicity than would be found in any other kind of animal, but some of them show very considerable complexity of structure, and perhaps, if various organs be considered, are really more complicated than some of the simplest of many-celled animals. There is, however, a fundamental difference associated with the single-celled condition that is most strikingly shown in the development. Since they are composed of single cells, it follows that there is no formation of germ layers in their development, but that whenever a division of cells occurs, the result is the formation of distinct individuals or at the most of colonies or aggregations of cells, each one being practically independent. While all are essentially microscopic, a few are large enough to be visible without magnification, but none of them can be studied without the assistance of a microscope.

They possess the essential part of a typical cell; that is, they consist of a minute mass of protoplasm which includes the nucleus and may possess a more or less definite wall. Along with these they bear locomotory structures of one kind or another, and some form of locomotion is present in practically all forms. Exceptions occur, for a large part of the lifetime, in some of the parasitic species.

One of the most common of the representative forms is the Amœba, a minute, extremely simple form, that occurs in almost any body of quiet water, and will be found most readily upon

submerged leaves or in the ooze adhering to sticks or other submerged objects. Seen under the microscope, this appears as a very minute particle of motile substance, usually moving with a peculiar flowing motion, the extension occurring in the form of irregular projections called **pseudopodia**. These may be protruded or withdrawn, or in some cases the whole animal will

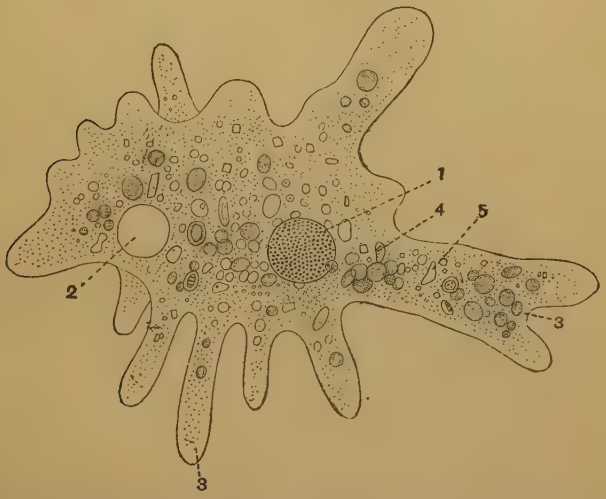


FIG. 1. — **Amœba proteus**, × 330. *1*, nucleus; *2*, contractile vacuole; *3*, pseudopodia; outer clear portion, ectosarc, inner granular, endosarc; *4*, food vacuoles; *5*, grains of sand. (After Gruber, from Shipley and McBride.)

appear to flow into one of these extensions. Often this results in a steady movement or translation, so that the animal will progress slowly across the field of vision. Examined closely, it will be found to consist of two rather distinct portions, an outer clear or more transparent part, the **ectosarc**, and a central, more granular and somewhat liquid portion, the **endosarc**. The latter may often be seen flowing in somewhat definite currents within the limit of the ectosarc. Within it will be seen also some larger granules of food material inclosed in **food vacuoles**, sometimes

including such distinct organisms as diatoms or desmids. There will also be noticed a distinct, usually more brilliant part, the **nucleus**, which is the essential structure in the division of the cell. **Contractile vacuoles** will be seen from time to time and form gradually as clear pinkish globules within the cytoplasm, and then suddenly disappear by a rapid contraction. The contents of the vacuole are usually ejected from the cell. We have already noticed the manner of locomotion, and it will usually be possible to see also the method of feeding. This is very simple, the Amœba merely flowing around the objects which it uses as food, and which thus become inclosed in the cytoplasm and their nutritive contents digested and absorbed into the protoplasm of the cell. The indigestible portions are then slowly ejected from the cell surface. There is no circulation except the movement of the protoplasm, and respiration consists in the absorption of oxygen from the surrounding water and the elimination of carbon dioxide.

It is believed that the contractile vacuole represents the system of excretion, the waste products of the activity of the protoplasm being collected in the contractile vacuole and from this ejected to the surface.

The mode of multiplication in Amœba is extremely simple, but involves, doubtless, a complex set of changes in the nucleus. Before division there is a distinct separation of the nuclear parts and the formation of two distinct nuclei which separate from each other, and following this, by gradual constriction of the cell walls, the mass of protoplasm is completely divided, each part including one of the new nuclei. Each of the resulting Amœbæ may later divide in a similar manner, and this process of division may go on indefinitely, resulting in the production of a number of individuals. Under certain conditions, however, the cell will contract into a globular form, the outer wall becoming hard and inactive, and the whole cell assume a resting, **encysted**, condition in which it will stand a great amount of drying and cold, and some degree of heat. It will regain its activity at any time with suitable conditions of moisture and temperature. It will be seen,

then, that the Amœba possesses locomotion, nutrition, the power of reproduction, and since it responds by contraction to stimulation, it shows also the function of irritability.

The Protozoa illustrate the fundamental activities of animal life and may serve as examples of the principles of **animal behavior.** Movement, which is characteristic of all animals and primarily due to contractility of protoplasm, may be stimulated by various external forces, and possibly by certain internal factors. So far as external forces are concerned there is opportunity for experimentation, and considerable progress has been made in determining the nature of these external stimuli and the responses that are made to them. These responses, or **tropisms**, have been classified with reference to character of stimuli, as for light, **phototropism** or **phototaxis**, and an organism attracted by light is said to be **positively** phototropic, or if repelled, **negatively** phototropic. The response to gravity is **geotropism**; to chemical stimuli (as in taste or smell), **chemotropism**; to electricity or magnetism, **electrotropism**; to contact, **thigmotropism**; to moisture, **hydrotropism**; to wind, **anemotropism**; to heat, **thermotropism**; to current (of air or water), **rheotropism**; to food, **trophotropism**, etc. It may be noted also that the same organism may at one time be positive and at another negative to the same stimulus or may respond in a different manner to different intensities of the same stimulus.

It must be admitted that in addition to the movements that seem to rest solely on external stimuli and which can therefore be studied by direct experiment, there are other movements, especially those associated with reproductive processes, growth, metamorphosis, etc., that are not to be explained in such a simple manner, but are in effect due to certain internal and perhaps self-regulated forces that cannot be tested by the same methods. Of these we are largely ignorant, though it is not to be granted that they cannot be studied or explained by experimental methods; such activities become more complex and difficult with the greater complexity of organisms. The simple single-celled organism may respond directly to the application of a local single stimulus, while

an animal with complex sensory structures responds by the correlated action of sense organs, nervous system, and muscles. It acts as a unit, and its action may be self-regulated, at least to the extent of selection or combination for various stimuli acting at the same time.

In the mode of multiplication the Protozoa give us the plan of growth and cell formation for all animals. Each cell is capable of a process of division which, formerly supposed to be a simple process, is known to involve some very intricate steps. The whole process, known as **mitosis** or **karyokinesis**, will be described briefly. The entire cell, nucleus as well as cytoplasm, is concerned, but the nuclear material seems to be particularly con-

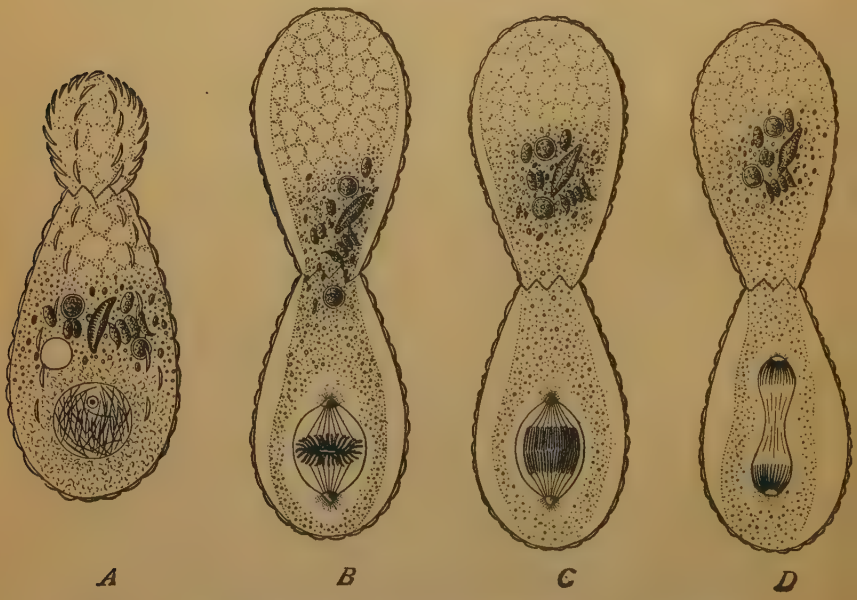


FIG. 2. — Division (budding) of **Euglypha alveolata** Duj. The nucleus is shown in different stages of mitosis. The shell plates occurring in this species are stored in the endoplasm around the nucleus and stream out with part of the protoplasm to form daughter cells before nucleus is entirely divided. (After Schewiakoff, from Calkins' *Protozoa*.)

cerned in the process. The first steps in the process appear as a gathering of the chromatin granules of the nucleus into a definite coiled thread which splits lengthwise, so that the parts of each resulting thread are duplicates of the other. These break transversely into V-shaped bodies which move from their equatorial position toward the poles of the cell toward the centrosome or attraction spheres, after which the cytoplasm gradually separates along the equatorial plane. When the division is complete there are two cells, the contents of each being a duplicate of the other, and both possessing the identical characteristics of the original cell from which they were formed. With the absorption of food they may soon acquire the size of the original cell and the division process may be repeated. Such in brief is the mode of cell division, not only in the protozoa where the cells as a rule separate and lead an independent existence, but throughout all the higher groups of animals where the cells after division remain aggregated together to form tissues. The most important variations from this process are in the union of two cells, **fertilization**, and the consequent blending of chromatin elements, which prevails among the many-celled animals and which is referred to in another place.

Review of Classes of Protozoa

The subdivisions of Protozoa are based upon the difference in the organs for locomotion and the complexity of the digestive apparatus and to some extent upon the methods of division or reproduction. They show a graded series from the simpler forms like the Amœba to complex and quite specialized forms like the Paramœcium and Vorticella.

Class Rhizopoda

This group includes the simpler forms, and is characterized by the absence of permanent locomotor structures. The cell may be entirely without definite wall or covering or may be pro-

tected within a case formed by minute particles of sand or earth, or a chitinous wall, and in still other cases by a cover of flinty shells which may be chambered or perforated in a variety of ways. In all, the locomotion is dependent upon the flowing out of portions of the protoplasmic mass, forming a lobe-like protrusion, or in some forms slender thread-like extensions called pseudopodia, these varying greatly in thickness or definiteness of shape. The cell includes the contractile vacuoles, food material, and nucleus. The group is quite large, including a large number of different forms, some of them extremely beautiful on account of the shells which are formed about them. There are a few which come directly into relation with man.

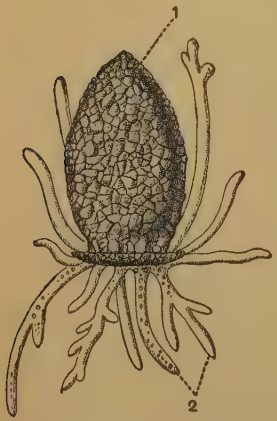


FIG. 3. — **Difflugia urceolata**, × 100. *1*, shell composed of particles of sand; *2*, pseudopodia. (After Leidy.)

Amœba, already described, and which is present in almost every pool of quiet water, and is distributed universally over the world, is the simplest organism which we can easily examine. The species of Difflugia resemble Amœbæ with the difference that they have a protecting case formed of minute particles of sand or earth, while in Arcella the protective circular flattened wall is chitinoid in character, with an aperture on one side for the extrusion of the pseudopodia. These forms are common fresh-water examples. The Foraminifera are abundant marine forms, and their shells on sinking to the bottom build up thick strata of limy mud which in the course of time forms a chalk deposit. The immense strata of chalk in Europe are composed of aggregations of such shells in connection with others of similar lime-secreting character. The Radiolarians are also marine, and secrete siliceous or flinty shells instead of limy

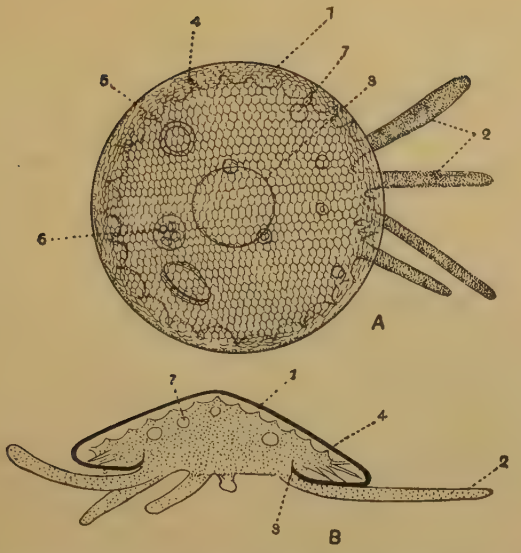


FIG. 4. — **Arcella discoides**, × 500. A, seen from above; B, seen from side, optical section; *1*, shell; *2*, pseudopodia; *3*, edge of opening into shell; *4*, thread attaching animal to interior of shell; *5*, nucleus; *6*, food vacuole; *7*, gas vacuole. (After Leidy.)

FIG. 5. — Chalk from cretaceous deposits of Kansas, showing various kinds of foraminiferal shells. (Drawn from photo by Geol. Surv. of Iowa, after Scott.)

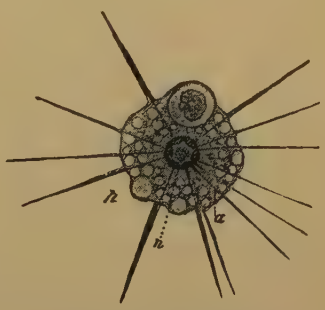


FIG. 6. — **Actinophrys sol.** *a*, axial filaments of pseudopods; *n*, nucleus; *p*, pseudopod. (From Lang's *Comparative Anatomy*, after Greenacher.)

ones, and these when preserved in sediment give rise to a siliceous rock. In both of these groups it may be seen that we have a basis for extensive and important rock formations. The depositions have been formed, of course, during the lapse of a great

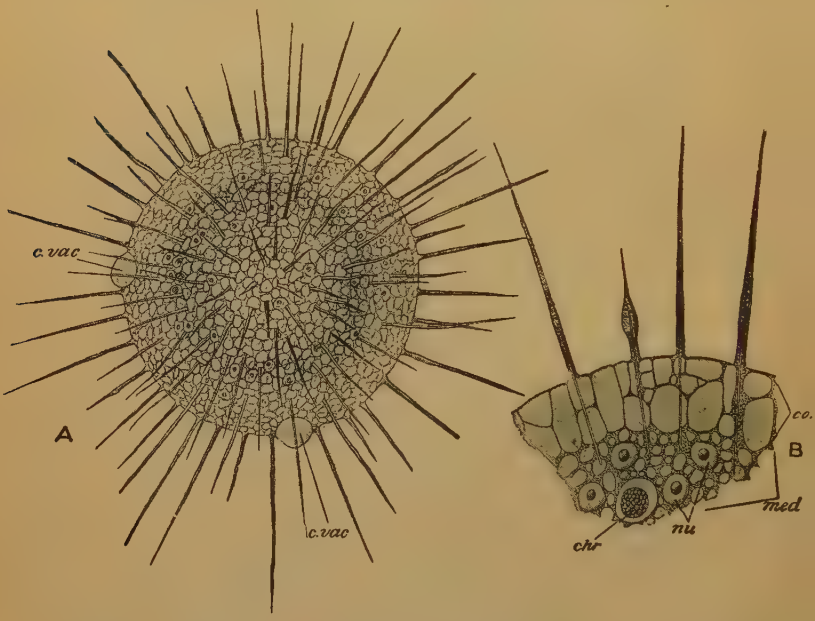


FIG. 7. — **Actinosphærium eichhornii**. A, the entire organism; B, a small portion, highly magnified; *chr*, chromatophore; *cort*, cortex; *c. vac*, contractile vacuole; *med*, medulla; *nu*, nuclei. (From Bütschli's *Protozoa*, after Hertwig and Lesser.)

length of time in the past, although similar deposits are being made in the bottom of the ocean at the present time. A few of the species are parasitic, and some of them are the source of troublesome disease in man and other animals, but they are not so extremely parasitic as the members of the following class.

The difference in kind of pseudopodia is used as a basis for

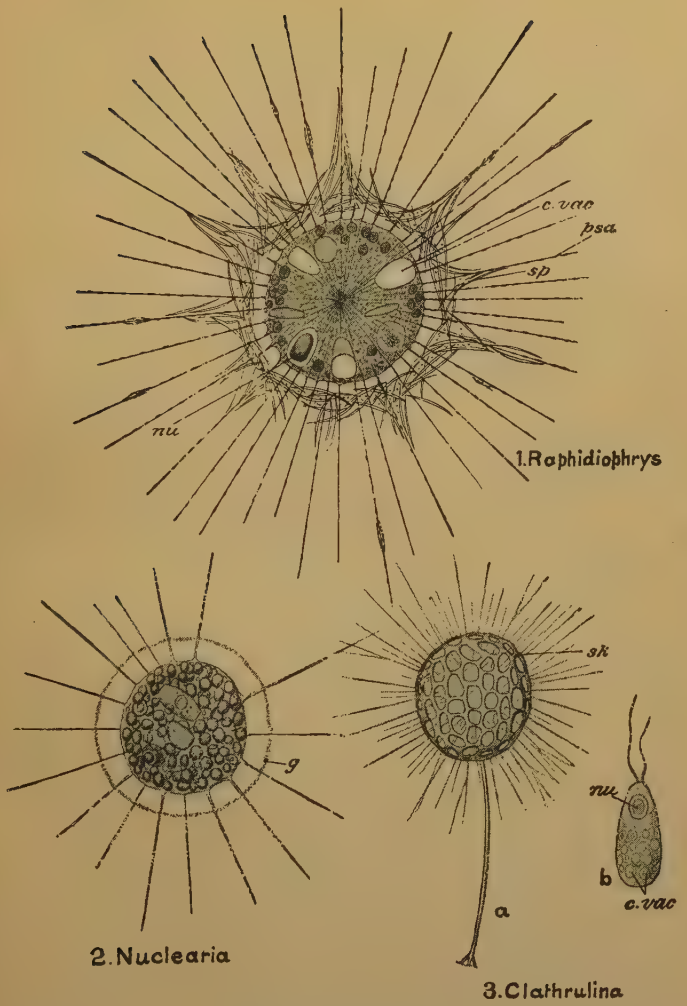


FIG. 8. — Various forms of **Heliozoa**. *3a*, the entire animal; *3b*, the flagellula; *c. vac*, contractile vacuole; *g*, gelatinous investment; *nu*, nucleus; *psd*, pseudopods; *sk*, siliceous skeleton; *sp*, spicules. (From Bütschli's *Protozoa*, after Schulze and Greeff.)

dividing the group; those with lobe-like pseudopodia are included in the order Lobosa and those with thread-like pseudopodia in the groups Heliozoa, Foraminifera, and Radiolaria; of these latter three, Heliozoa includes mostly naked forms; Foraminifera, those with calcareous shells; and Radiolaria, those with siliceous shells. The two latter are practically all marine.

Class Sporozoa

This group includes the parasitic protozoans, and they are characterized by absence of locomotor structures, at least during those stages which may be considered as the matured form.

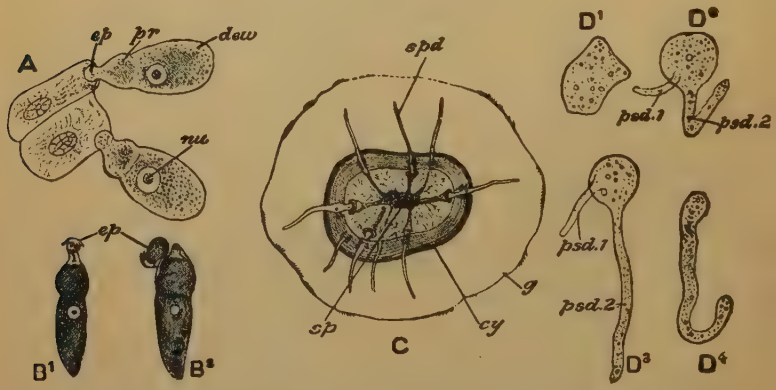


Fig. 9. — **Gregarina.** A, two specimens of *G. blattarum* partly imbedded in enteric epithelial cells of cockroach; B¹, B², two specimens of *G. dujardini;* in B² the epimerite (*ep*) is cast off; C, cyst of *G. blattarum*, from which most of the spores have been discharged; D, four stages in the development of *G. gigantea; cy*, cyst; *deu*, deutomerite; *ep*, epimerite; *g*, gelatinous investment of cyst; *nu*, nucleus; *pr*, protomerite; *psd, 1*, short pseudopod; *psd. 2*, long pseudopod; *sp*, mass of spores; *spd*, sporoducts. (From Bütschli's *Protozoa.*)

Their nutrition is derived by absorption, and they show little or no evidences of food vacuoles or other internal structures aside from the nucleus. The cell wall is thickened, and in many

cases constructed in such a manner as to form apparently two chambers or segments of the individual. They occur in many different animals and are specially noticeable in the lobster, grasshopper, certain beetles, and as muscle or blood parasites in vertebrates. The Gregarina of the lobster is one of the largest species and the mature individual reaches a length of from one half to three quarters of an inch, and is quite cylindrical. The cell wall is practically structureless. They occur in various parts of the alimentary tract. The adults have a slight degree of movement and give rise to numbers of minute individuals which enter the cells and remain in these during the series of changes, returning when mature to the alimentary canal. Other species occur commonly in the earthworm, affecting the male reproductive organ and producing a cyst within which a large number of minute spindle-shaped spores are developed. The spores divide into a number of small crescent-shaped bodies, each one of which may be developed into a new individual.

The most important members of the group, however, are those which occur as blood parasites in higher animals, some of which at least are dependent upon some particular mode of transmission for their entrance into different individuals. One of the best known of these is the one producing malaria in man and known as the *Hæmamœba laverani*. It has been definitely proven to be the cause of malarial fever, and it is also definitely determined that it is transmitted from one person to another by means of mosquitoes belonging to a particular genus, *Anopheles*. Another species produces the well-known Texas fever of the southern United States, the carrier in that case being the common cattle tick. The relation of these forms as disease carriers will be mentioned in another section. Aside from these forms there are others which affect the muscles, — the Sarcosporida, occurring in mammals; the Myxosporida, which are mostly parasitic in fishes, affecting the skin or internal organs; the Coccidia, which affect more commonly the liver and the intestines and some species of which produce serious diseases.

Class Mastigophora

The members of this group differ essentially from the preceding classes in the possession of permanent locomotory structures in the form of flagella. They abound in bodies of water both fresh and salt and in some forms produce large colonies of individuals adhering together.

A very common and abundant example of this class is the Euglena, which may be found in almost any body of stagnant water. The usual form for these species is an elongate, nearly cylindrical

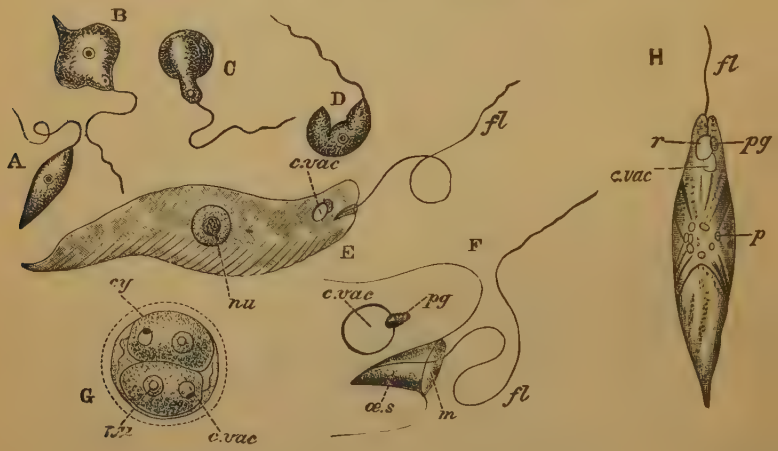


Fig. 10. — **Euglena viridis.** A–D, four views illustrating euglenoid movements; E and H, enlarged views; F, anterior end further enlarged; G, resting form after binary fission; *c.vac*, contractile vacuole in H, reservoir in E and F; *cy*, cyst; *fl*, flagellum; *m*, mouth; *nu*, nucleus; *œs*, gullet; *p*, paramylum bodies; *pg*, pigment spot; *r* (in H), reservoir. (From Parker's *Biology* after Kent and Klebs.)

shape tapering to a rather sharp point at the end of the body opposite the flagella. The flagella may be interpreted as representing the head end, as it is attached within a little conical cavity which receives particles of food matter and in this respect is similar to a mouth, although it is not connected with any internal cavity for digestion. Near the base of the flagellum is a small

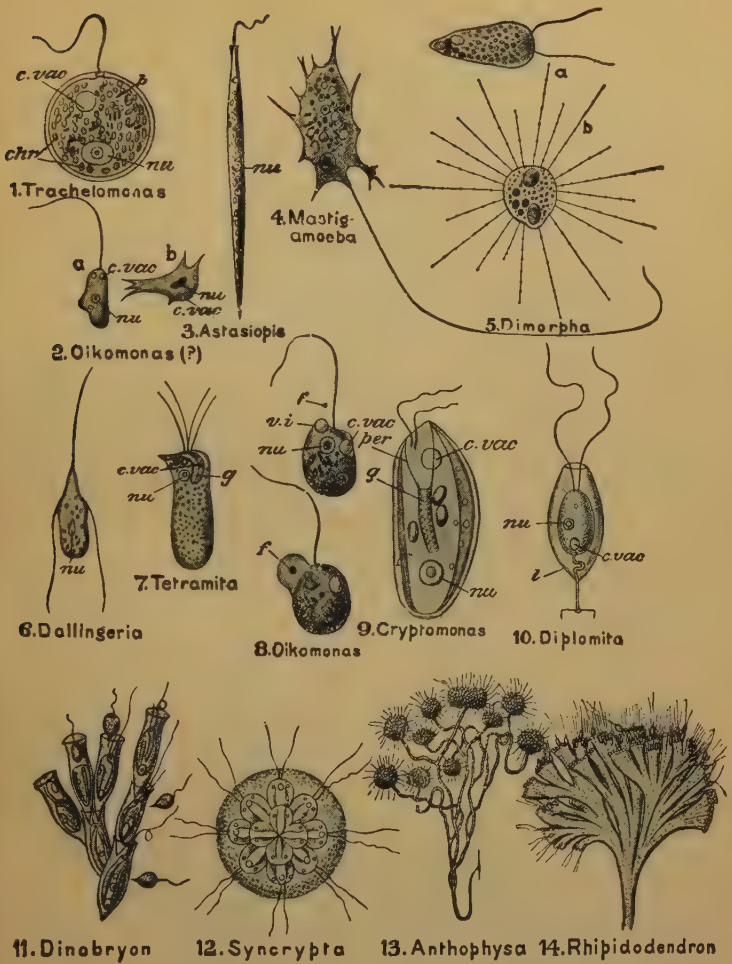


FIG. 11. — Various forms of **Mastigophora**. — In *2*, flagellate (*a*) and amœboid (*b*) phases are shown; in *5*, flagellate (*a*) and heliozoan (*b*) phases; in *8* are shown two stages in the ingestion of a food particle (*f*) ; *chr*, chromatophores; *c.vac*, contractile vacuole; *f*, food particle; *g*, gullet; *nu*, nucleus; *l*, lorica; *p*, protoplasm; *per*, peristome; *v.i*, vacuole of ingestion. (Mostly from Bütschli's *Protozoa*, after various authors.)

reddish spot which is supposed to be sensitive to light and is sometimes spoken of as the eye spot. There is, of course, no distinct vision, but the pigment granules of this minute area appear to interrupt light rays and may enable the animal to distinguish between light and darkness.

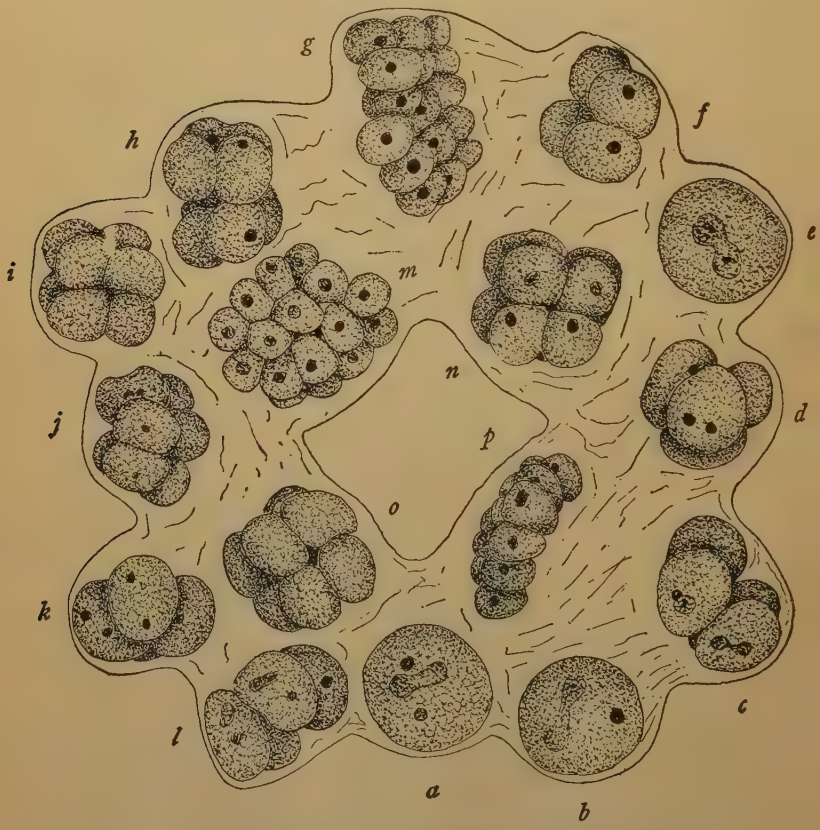


FIG. 12. — Division of **Gonium pectorale** O.F.M. showing formation of cell colonies. *a*, *b*, and *e*, undivided cells; *c*, *d*, *f*, *k*, and *l*, 4-celled stages; *h*, *i*, *j*, *n*, *o*, 8-celled stages; *g*, *m*, and *p*, 12–16-celled stages. (From Calkins' *Protozoa*.)

Some forms of special interest in this group are those which in dividing adhere together so as to form colonies, although each individual retains its independent nutritive process, and in one of these, the Gonium, there is formed a small cluster of cells, sixteen in number, which are held together in a gelatinous mass and retain a simple flattened form. In another form, the Pandorina, the cells resulting from repeated division arrange themselves in a spherical form with a central cavity, so that they approach closely to the condition represented in the sixteen-celled blastula of higher animals, while in the Eudorina, which reaches this same condition, there is some differentiation of the cells composing the mass, and in conjugation the larger and smaller cells unite. A still more specialized condition, with greater difference in the conjugating cells, is found in Volvox. These conditions of cell aggregation are at least suggestive of the means by which many-celled animals may have been first developed from the single-celled forms. The resemblance is especially significant if a comparison is made between such forms as Pandorina or Eudorina with the early stages of some higher form in which there is a regular cell division up to the sixteen- or thirty-two-celled stage. We must not, however, forget that such a resemblance may have occurred not necessarily because of a common ancestry; but we must also appreciate the full importance of the infolding of a portion of the cell aggregate to form a gastrula with its differentiation of cells into ectoderm and endoderm, which seems to be the dividing line between the many-celled and the single-celled animals. It is difficult, however, to conceive of the origin of the gastrular form except by way of the blastula and its derivation from an aggregation of cells similar to those occurring in the colonial protozoans. The appearance of two distinct forms of cells representing what may properly be considered male and female forms is also particularly suggestive and is, of course, the basis for referring the development of sex cells in the other animals to these particular kinds of Protozoa; and if Protozoa and Metazoa are looked upon as of similar derivation, we must carry

the origin of this separation into distinct sex cells back to some very early form of which the existing species of Eudorina and Volvox may be considered as simple parallel types.

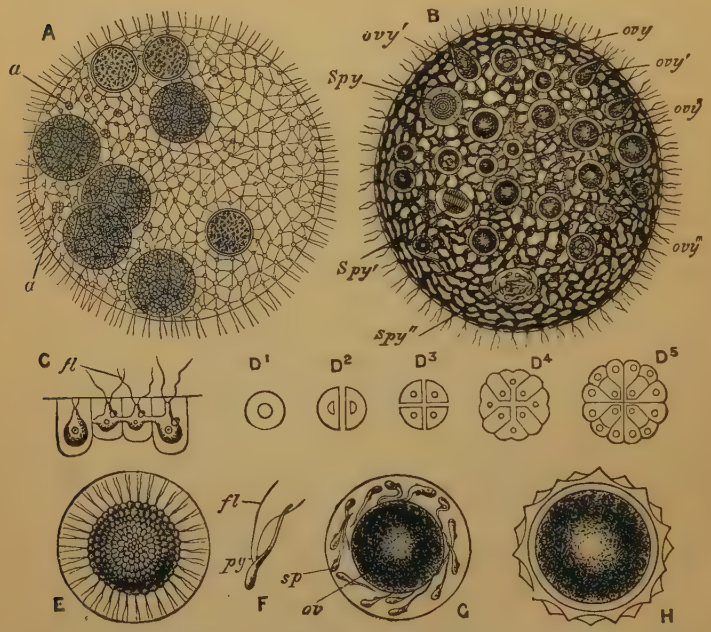


FIG. 13. — **Volvox globator**. A, entire colony, inclosing several daughter colonies; B, the same during sexual maturity; C, four zooids in optical section; D^1–D^6, asexual formation of daughter colony; E, zooid which has become converted into a mass of microgametes; F, microgamete; G, megagamete surrounded by microgametes: H, zygote; *a*, early stages in the formation of daughter colonies; *fl*, flagellum; *ov*, *ovy*, megagametes; *pg*, pigment spot; *spy*, zooids containing microgametes. (From Parker's *Biology*, after Cohn and Kirchner.)

One of the most important members of the group is *Trypanosoma*, which is recognized as the cause of sleeping sickness in Africa, and another species of which produces the serious disease Surra in Oriental countries.

Class Ciliata

In this division the body is provided with minute cilia which are distributed in some cases over the entire outer surface, and in others forming a circuit around the mouth opening, serving for purposes of locomotion and for the bringing of food material into the mouth opening. There are several distinct types of structure, and we can consider only two or three of these in any detail.

The Paramœcium, or Slipper Animalcule, is a flattened oval, slipper-shaped animal, the body surface being provided with cilia which are quite uniformly distributed over the surface. At the anterior and posterior ends these are somewhat longer, and a band of longer cilia surrounds the mouth. It moves with a rapid direct motion, darting here and there, and is able to adjust itself to some extent in working its way among objects in the water. Distinct currents are created by the oral cilia, food particles being drawn down to the base of this and into the opening, which extends into what is called the esophagus, and from which food particles are absorbed into the protoplasm of the cell. While the outer portion is definite in outline and fairly rigid, the central portion is more liquid, and currents of granular protoplasm may be seen streaming from one part to another within the cell. The nucleus is a dense oval body consisting of a large and a small portion situated near the central part, and at either end there is a conspicuous contractible vacuole which appears and disappears in quite regular rhythmic order. This contracting vacuole presents a central globular form which gradually increases in size until it reaches a certain maximum and then suddenly disappears. At the same time, under certain conditions, a series of radiating spaces will be noticed which appear to be filled with the same kind of fluid contained in the central vacuole. From this the vacuole is refilled, and the contents thus gathered are presumably ejected from the cell by the force of the contraction. While not perfectly regular, there is usually some alternation in contraction between the two vacuoles of the opposite ends of the

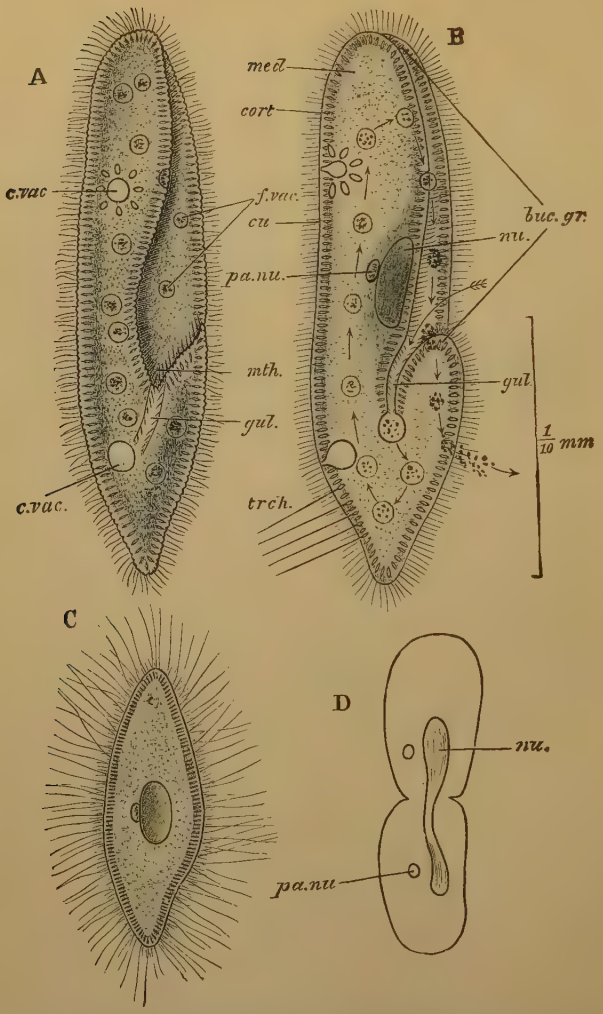


FIG. 14. — **Paramœcium caudatum.** A, the living animal from the ventral aspect; B, the same in optical section; the arrow shows the course taken by food particles; C, a specimen which has discharged its trichocysts; D, diagram of binary fission; *buc.gr*, buccal groove; *cort*, cortex; *cu*, cuticle; *c.vac*, contractile vacuole; *f.vac*, food vacuole; *gul*, gullet; *med*, medulla; *nu*, meganucleus; *pa.nu*, micronucleus; *trch*, trichocysts. (From Parker's *Biology*.)

body. Division may occur by transverse fission preceded by the division of the nucleus, and conjugation between two individuals is of rather frequent occurrence. During this process there is an exchange of nuclear material in the form of micronuclei, so that at the end of the process each individual has acquired nuclear material from the other. The details of this nuclear division are quite complex, and it has been illustrated diagrammatically to show the consequence of this transfer of nuclear elements. Calkins has shown experimentally that without this process of conjugation there is in time a deterioration of the Paramœcium as indicated by its rapidity of growth, ability to multiply by fission, and other activities. He has shown also that this deterioration may in some degree be forestalled by furnishing a change in nutritive material. Stylonichia shows a greater specialization of the cilia in spine-like appendages. Another common form, the trumpet animalcule, or *Stentor*, differs from the Paramœcium in having a trumpet-shaped form, the small end usually attached and the circle of cilia at the opposite end,

FIG. 15. — **Stentor.** *m*, mouth ; *v.c*, contractile vacuole; *n*, nucleus; *f.v*, food vacuole. (Drawn by Miss Freda Detmers.)

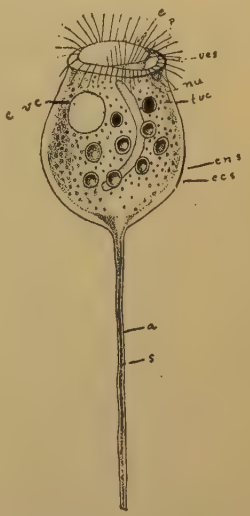


FIG. 16. — **Vorticella nebulifera.** *p*, peristome; *ves*, vestibule; *nu*, nucleus; *c.v.c*, contractile vacuole; *f.v.c*, food vacuole; *e.n.s*, endosarc; *e.c.s*, ectosarc; *e*, ciliated disc epistome; *s*, stem; *a*, axis of stem. (From drawing by Miss Freda Detmers.)

forming strong currents of water which bring food into the mouth cavity. The nucleus is quite different, having an elongated nodulated form, and there is a large contracting vacuole.

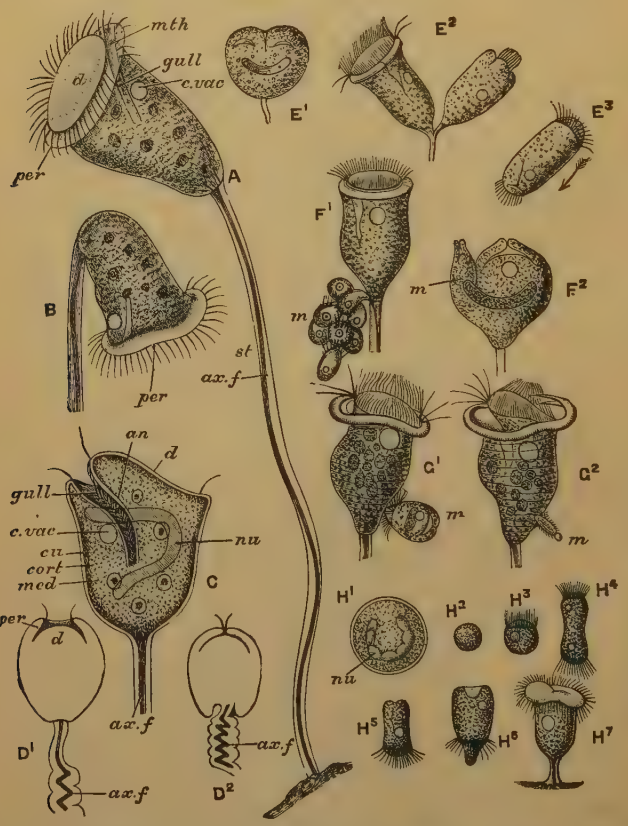


FIG. 17. — **Vorticella.** A, B, living specimens in different positions; C, optical section; D^1, D^2, diagrams illustrating coiling of stalk; E^1, E^2, two stages in binary fission; E^3, free zooid; F^1, F^2, division into mega- and microzooids; G^1, G^2, conjugation; H^1, multiple fission of encysted form; H^2, H^8, development of spores; *ax.f*, axial fiber; *cort*, cortex; *cu*, cuticle; *c.vac*, contractile vacuole; *d*, disc; *gull*, gullet; *m*, microzooid; *mth*, mouth; *nu*, meganucleus; *per*, peristome. (From Parker's *Biology*, partly after Saville Kent.)

The Stentor may swim freely at times or attach itself apparently at will, and it multiplies by longitudinal fission.

The bell animalcule, or *Vorticella*, may be compared to the Stentor, with the difference that it has a long contractile stalk. The shape is like a bell, the rim being opposite to the stalk and provided with a circle of cilia, the movements of which draw currents of water into the mouth. Other parts of the cell are not provided with cilia, except that at times when the bell breaks away from the stalk a circle of cilia is developed near the base, this frequently being used, especially in locomotion. By means of the stalk the Vorticella pushes out to a distance from the point of attachment and opens the circle of cilia in clear water, producing currents which are to supply it with food.

On the approach of any irritating body the cilia are retracted and the stalk shortened by the sudden contraction of the thread into a spiral the center of which contains a muscle-like contractile fiber. The nucleus is curved, horseshoe-shaped, and quite large. The Vorticella multiplies by longitudinal fission, and frequently numerous individuals are found in a colony, each possessing its independent stalk. At the time of encystment the bell breaks loose from the stalk and may swim about, coming finally to rest, the body becoming rigid and forming a strong tough cyst, within which the protoplasm is protected from dryness. Often preceding these conditions two kinds of individuals appear, one much smaller than the other, usually more distinctly motile, which has arisen by division, and conjugation takes place between these smaller motile individuals and the larger less motile forms.

This class includes some of the most beautiful of the protozoans and exhibits a very great variety of adaptation, but except as they furnish food for other organisms they have no very striking importance from an economic standpoint.

The Economic Importance of Protozoa

The Protozoa occur in countless numbers in almost all bodies of water, and while of great importance in many ways, as furnish-

ing food for higher forms of life, are sometimes the basis of serious pollution of water and the basis for the formation of extensive deposits of rock. Their most conspicuous relation at the present time is in connection with the fact that they are the cause of many serious diseases, such as malaria, yellow fever, and the sleeping sickness in man, the Texas fever in cattle, and other diseases among domestic animals. Aside from the immense importance of these diseases, the mode of their transmission is of especial interest, and a short review of a few of the most important cases will be in place.

While the protozoan character of malaria was suspected some time since, it was not until about fifteen years ago that its definite relation and the means of its transmission was positively determined. The protozoan causing the disease is an amœba-like species which occurs in the blood, particularly within the red corpuscles, and during certain stages swarms in immense numbers in the blood plasma. In this form it may be taken into the alimentary tract of a mosquito, and passes through certain stages, during which it migrates from the stomach and through the tissues to the salivary glands, and there reaches the stage in which it may be introduced into another person, provided the mosquito has an opportunity to bite again. These stages of development are best shown in the plate, which gives the successive stages of development and the forms occurring in the human species and those stages of development in the mosquito. The dependence of this disease upon transmission by mosquitoes has been proven by most careful experiments both by preventing malaria in malarial districts by the exclusion of mosquitoes and by the inoculation of malaria in localities where that disease has been unknown by giving infected mosquitoes opportunity to bite a healthy person.

The condition in yellow fever is very similar, although the exact protozoan organism has not been actually seen, probably because of its extreme minuteness or more likely because of difficulty in staining processes. Its transmission by a certain kind of mosquito, the Stegomyia, has, however, been demonstrated by the most

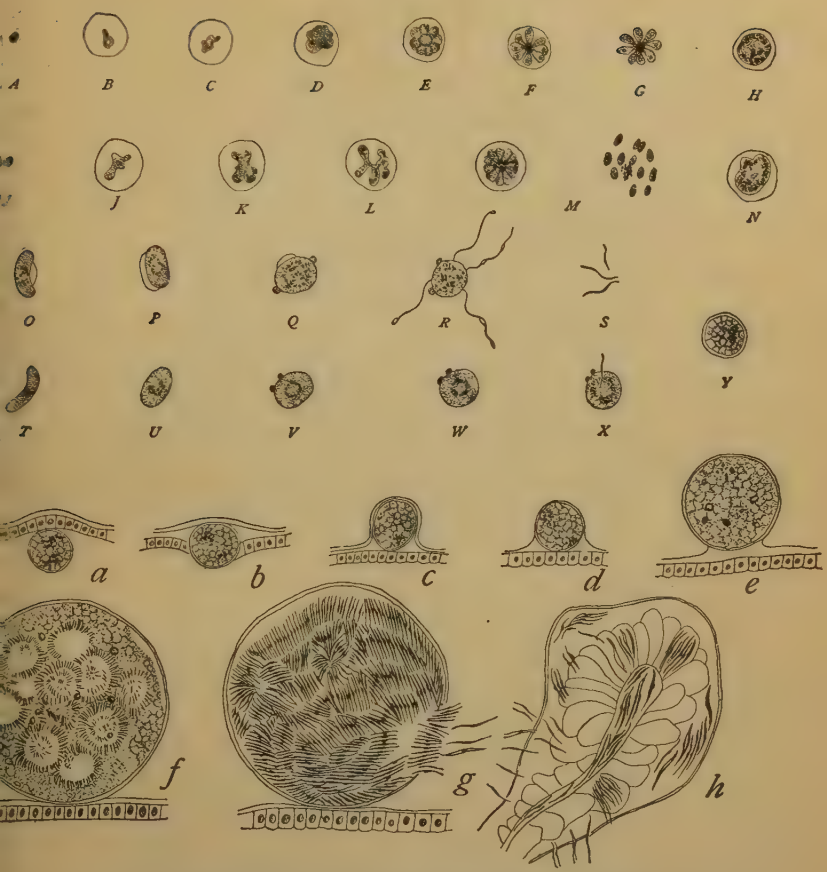


FIG. 18. — Life history of sporozoan causing malaria. A–F, stages in the development of merozoites; A–I, the sporozoite; B, C, D, and J, K, L, the growing sporozoite in blood corpuscles; E, asexual reproduction (schizogony); F, G, and M, liberation of merozoites and melanin granules; O, W, stages in the development of sexual individuals; R, polymitus form; S, fully developed microgametes; T–W, development of the female individual (macrogamete); X, fertilization of a macrogamete by a microgamete; Y, the fertilized cell copula, with its vitelline membrane; *a–e*, the copula in the stomach of the mosquito (**Anopheles sp.**); *b*, the copula penetrating the epithelium which lines the stomach of *Anopheles; b, c, d, e*, growth of the copula in the body cavity of *Anopheles.* The small sphærules at V, W, and X are supposed to be analogous to polar bodies of metazoan eggs. *f*, sporulation in the body cavity of *Anopheles; g*, liberation of the sporozoites; *h*, salivary gland (in section), with sporozoites in the lumen, in the cells, and penetrating the membrane. (After Ross and Fielding-Ould, from Calkins' *Protozoa.*)

exact tests, and at present all methods of quarantine and of control for this disease are based strictly upon the fact of such means of infection.

The sleeping sickness in Africa is due to a somewhat different protozoan, the *Trypanosoma*, but is due to the occurrence of this organism in the blood much as in malaria. Its transmission is due to a species of Tsetse fly, *Glossina palpalis*, and Koch has recently reached the conclusion that the crocodile is also a host and serves to perpetuate the disease.

Texas fever in cattle, which has been a great scourge and a most serious handicap to the cattle industry in the Southern States, is now known to be caused by a protozoan, and it has been determined that its introduction into cattle is dependent upon

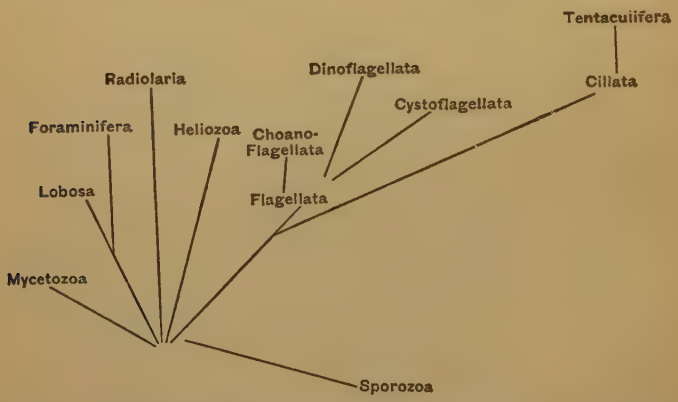


FIG. 19. — Diagram showing the mutual relationships of the chief groups of Protozoa. (After Parker and Haswell.)

the attacks of the cattle tick, certain stages of the organism developing within the tick and being carried through the mouth of this parasite into the blood of the cattle. This mode of infection having been proven, a careful study of the tick, showing that it is dependent upon cattle for its existence, has made it possible to devise methods of prevention, and at present it is believed that

by a process of rotation from field to field with sufficient time to permit the death of all the ticks, a complete extermination of that parasite may be accomplished, and thereby the complete suppression of Texas fever result. This may at least be accomplished on individual farms where the owner is willing to take the necessary means to accomplish this result. Definite plans for such treatment are now given in the government bulletins and the experiment stations of the states where this disease is most troublesome.

Other diseases connected with Protozoa are the hæmaglobinuria of cattle and sheep, caused by *Babesia bovis*, and the silkworm disease, pébrine, due to *Glugea bombicis*.

CHAPTER III

SPONGES — HYDROIDS — POLYPS

Porifera

Although sponges have little resemblance to the more active forms of animals, they show in their development and method of nutrition their distinct animal characteristics. They are all, except during a brief larval period, attached firmly to some submerged object, and their growth very much resembles that of plants. The general plan of structure is for the surface of the body to be perforated by numerous minute apertures through which water is drawn into the internal canals, and to a central space from which water passes out through an opening termed the **osculum**. For the simpler sponges there may be a single osculum, the animal as a whole vase-shaped, but in all the more complicated forms the internal canals become numerously branched and complicated, and there may be a large number of oscula scattered over the surface. They feed upon minute aquatic organisms brought in with the currents of water and caught and digested by the endodermal cells. There are two distinct cell layers, the **ectodermal** and the **endodermal**, differing in character as well as function, the endodermal cells usually being provided with minute lashes, or **flagella**. Between the two cell layers is a more or less extensive mass, or **mesoglœa**, which is secreted between the cell layers and which in many sponges includes very many definite hard structures, the limy or flinty **spicules** and a variety of cells. In other cases a strong fibrous framework makes up an elastic supporting structure, the part which in common commercial sponges is left after the animal tissues have been decomposed and washed away.

It is worthy of note that we have here our first appearance of a many-celled structure with two definite cell layers and, notwithstanding the simplicity of sponges, the fact that the cell layers are formed in the same manner and occupy the same position as in all the higher groups of animals is good proof of their relationship to other many-celled forms. The simple arrangement of the cells, moreover, shows the possibility of the derivation of very simple sponge forms from the more complex cell aggregations which have been noted among Protozoa. Perhaps the most striking fact is found in the uniform invagination and formation of the gastrular cavity in sponges and all other Metazoa.

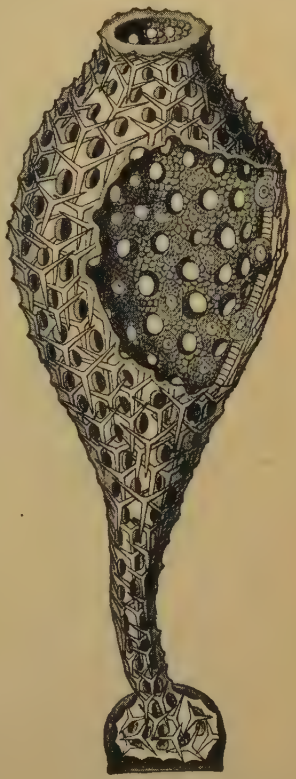
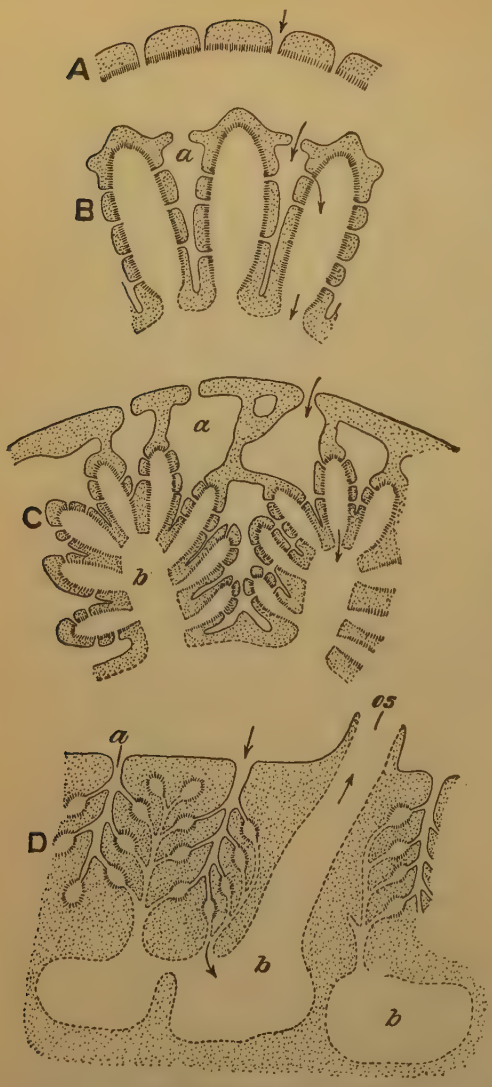


FIG. 20. — **Ascetta primordialis.** A portion of the wall of the vase-like sponge removed to show the paragastric cavity. (After Haeckel.)

Of the simpler sponges, the vase-shaped Grantia may be taken as an example. This reaches the size of three fourths to one inch in length and is attached by a small base and expands somewhat in the central part and contracts more slightly at the osculum; the calcareous spicules extending through the walls give it a rough, hairy appearance, and a fringe of longer spicules around the osculum suggest the petals of a flower; the surface of the body is perforated by numerous openings, the incurrent pores, these opening into incurrent canals, and these connecting by numerous apertures with radial canals lined with flagellate endoder-



mic cells; the inner ends of these canals open into a central space. A section of the animal shows a lining of endodermal cells throughout the canals and indicates a folding of ectoderm and endoderm layers. This, while not the most primitive form of sponge, is one of the simplest we have.

Based on plan of structure there are three distinct types of sponges: first, the

FIG. 21. — Diagram of the canal system of various sponges, the ectoderm denoted by a continuous narrow line; the flattened endoderm by an interrupted line; the flagellate endoderm by short parallel lines. A, cross-section through a part of the wall of an Ascon; B, cross-section through a part of the wall of a Sycon; C, cross section through a part of the wall of *Leucilla convexa;* D, vertical section through Oscarella; *a*, spaces of the incurrent canal system; *b*, spaces of the excurrent canal system; *os*, osculum. (After Korschelt and Heider.)

vase-shaped sponge, the ectoderm forming the outer wall and the endoderm forming a simple lining layer, the incurrent apertures passing directly into the inner space; this is termed the **ascon** type. Second, a form in which the cell layers are folded, giving rise to canals and incurrent orifices passing through the ectoderm to the endodermal layers which line other canals, which in turn open to a central space; this, or the **sycon** type, is represented by such forms as Grantia. Third, the **leucon** type, in which the folding of the germinal layers has gone still farther, the external openings passing into canals which may give rise to canals from which orifices leading through ectoderm to endoderm may pass. In these forms there is usually a somewhat spacious cavity lined with endoderm, which is termed the stomach, and from which canals lead to the main channel, opening into the oscula. It is evident that the ascon type corresponds to the simple gastrula with the addition of perforations, and it seems entirely warranted to conclude that this is the most primitive type of sponge structure and that the sycon and leucon types are derived from it by further infolding and specialization of cell layers.

The development of the sponge is of particular interest, as we have appearing in this group an arrangement of the germ layers which remains the type not only of the simplest forms but of all the many-celled animals. It comes the nearest, perhaps, to showing a change from an aggregate of single-celled animals to a distinct organism composed of many cells ranged primarily in the form of two layers. The sponge eggs are developed in the inner layer of cells, and they occupy some space in the mesoglœa, and when mature are liberated from the sponge and escape into the water. The egg is fertilized by union with a sperm cell, which, like the egg cell, is developed from special cells in the endoderm, the fertilization taking place after the liberation of the egg, and presumably in most cases in close proximity to the parent sponge. After fertilization the egg cell divides, the nucleus being the first part engaged in division, and the two cells resulting from this

division each divide, and the process goes on with regularity until the thirty-two or sixty-four cell stage is reached. At this time there begins to be apparent a change in the cells of one portion,

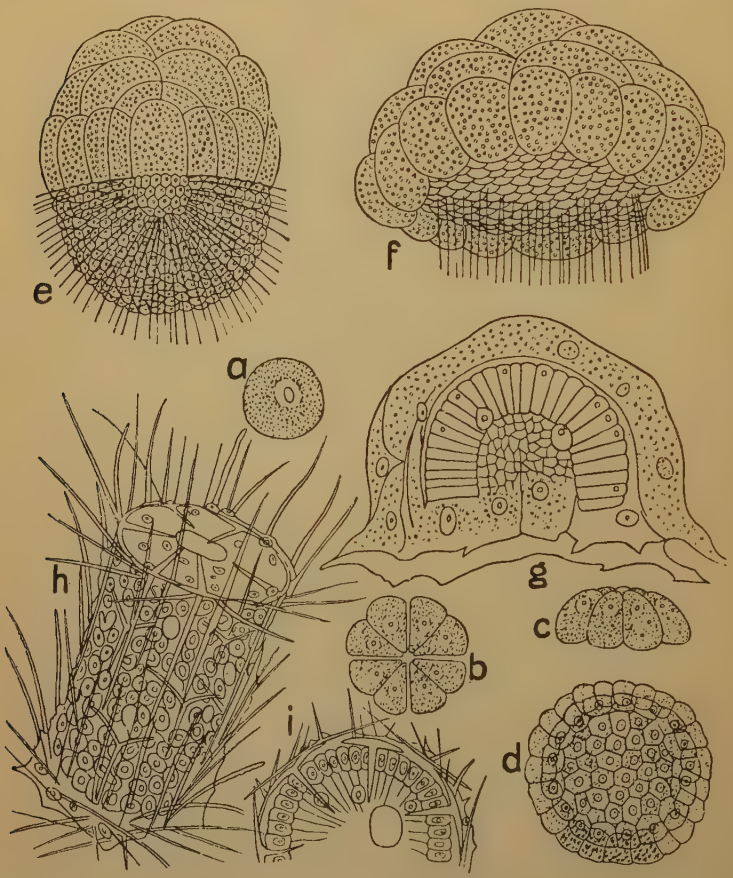


FIG. 22. — Development of **Sycon raphanus**. *a*, ovum ; *b*, *c*, ovum segmented, — *b*, as seen from above, *c*, lateral view; *d*, blastula; *e*, amphiblastula; *f*, commencement of invagination; *g*, gastrula attached by its oral face; *h*, *i*, young sponge, — *h*, lateral view; *i*, as seen from above. (From Sollas, after Schulze.)

these becoming larger and forming the lower part of the cell mass in which they occur, and beginning to push into the central cavity around which the single layer has been formed. In the globular form with a single layer of superficial cells, the **blastula**, there is no development of locomotory structure, but upon the cells which are to form the inner germ layer, the endoderm, there arise distinct lash-like structures, the **flagella**, and these flagella enable the organism to swim for a time. At this stage it may be considered a primitive gastrula, and such motion as the sponge possesses is carried on at this time. But shortly the embryo settles down with the lashes downward, and later these attach to the surface of the rock or other object upon which they rest. It is from this point on a permanently fixed body and develops away from the typical structure for the many-celled animals. Instead of forming a distinct alimentary tract the gastrula is closed, and the body increases in number of cells and at a point opposite to that of attachment the cells separate to form an osculum which remains as a permanent outlet for the water currents. By the separation of cells, the formation of minute pores passing through the cell layers at numerous points on the lateral surface, there is formed an incurrent orifice which permits of the inflow of water into the central cavity. The ciliated endoderm cells remain as the lining cells of the central cavity and the typical sponge structure is established.

The point, perhaps, of most interest in comparison with the colonial protozoan forms is to be found just before the invagination of the blastula, while the cells are still arranged in a spherical mass; for in this stage, especially if the cells are studied, there is a quite striking resemblance to the protozoan colony. This development, while indicating the primitive condition for the group, leads with farther growth to intricate structures which pass farther and farther from the general plan of structure for the many-celled animals.

Classifying sponges with reference to types already indicated, we may form groups which coincide also with the kind of spicules

FIG. 23. – Fresh-water sponge **Meyenia fluviatilis**, Sandusky Bay, showing form spread out over a flat surface.

formed, and, in general, sponges are separated into two classes, the calcareous and non-calcareous, the first having only calcareous spicules and the latter with flinty siliceous spicules, a fibrous network or no skeletal parts. In the latter group are included the fresh-water sponges that occur quite commonly in permanent bodies of water. These have a peculiar phase of life in the formation of statoblasts, which preserve the animal over winter.

Sponges have a wide range of usefulness and a very distinct commercial value, the more abundant forms being found in tropical seas. Gathering and preparing sponges for market forms a very important industry, especially in Florida and various parts of the Indian Ocean. The primitive method of securing them is simply to dredge or rake them from their attachment and to kill the animal tissue and decompose it, so as to have the skeleton freed from the cellular portion. The indiscriminate collecting results in depletion of the beds, and some definite control must be adopted to perpetuate the industry. This has been accomplished in Florida by developing a distinct system of sponge farming, the waters of a suitable depth being surveyed, platted, and leased, the individual lessees being allowed to control the planting and collecting from certain definite tracts, so that a proper period of growth may be allowed before the sponges are gathered. The planting consists of cutting up into minute fragments the species of sponge desired and scattering these over the bottoms which are suitable to their growth. After a period of two or three years necessary for sufficient growth, the sponges may be harvested and the tract replanted for another crop. Definite figures as to the extent of the commerce are not at hand, but we need only to call to mind the immense number of sponges which are marketed and the great variety of uses to which they are put, to appreciate the importance of the industry. Doubtless there are many areas in tropical waters where the industry can be greatly extended and can be expected to grow steadily with the demand for the product and with the adoption of proper regulations to promote methods of suitable culture.

Cœlenterata

The Cœlenterates are almost without exception marine animals and represent one of the primitive groups adapted to aquatic existence, and contain many of the simple characteristics of the most primitive forms. The group includes the jellyfish, coral polyps, hydroids, etc., and includes a quite large number of common forms. The general plan of symmetry is radial, the members being distributed around a common axis, and in many cases a plane cut through this axis in any direction will divide the animal into similar parts. In some cases, however, a certain amount of bilateral symmetry is evident in the distribution of the parts within the body. Commonly the body is cylindrical and attached at one end, the other being provided with a mouth opening which is surrounded by a number of tentacles. These are flexible structures capable of seizing and holding food material which is forced into the mouth opening. The body wall consists of two definite cell layers, an outer, or ectoderm, and an inner, or endoderm, between which there is a structureless layer or mass, the mesoglœa, of quite different thickness in different members of the group, in some cases a mere basal membrane between the cell layers and in others a large gelatinous mass within which spicules or other structures may be found. The mouth opens into a gastrula cavity, and in the simpler forms this opening is formed at the union of ectoderm and endoderm at the outer portion of the body, there being no infolded gullet, while in other forms the ectoderm is pushed downward into the body cavity, so that there is formed a sort of gullet which opens to the exterior through an aperture or mouth in which the ectoderm only is found. These two types of structure are the basis for the separation of the group into two main divisions, the first, or the **hydrula** type, being characteristic of the hydroids and related forms, while the second type, the **scyphula**, is characteristic of the Scyphozoa. In the latter form the gastrula cavity is usually divided into a number of chambers by septa, or partitions, that extend from the exterior wall to the

gullet. The ectoderm commonly includes numbers of nettling cells which are capable of expulsion, or of dart-like structures which have an irritating effect on the tissues of other animals and which are used in paralyzing the minute organisms on which the cœlenterate feeds, or as a means of defense against forms which are inimical. Special types of the group may be studied under the particular subdivisions.

Class Hydrozoa

The animals of this group are formed on the hydrula plan and have the reproductive cells developed in the ectoderm and present in many cases striking alternations between fixed and free forms.

A good example of the group, and the only common fresh-water form, is the Hydra, which occurs in two varieties, green and brown, known respectively as *Hydra viridis* and *Hydra fusca*. Except in color these are so nearly alike that one description will suffice. They are found commonly attached to submerged objects, especially on the roots of willows or other plants that may extend into the water, on the under side of the leaves of duckweed, or attached to floating aquatic vegetation. Kept in aquaria, they will frequently collect upon the glass surface, where their movements may be easily observed. While quite minute forms not much larger than the head of a pin when contracted, the body may be extended to the length of about half an inch, and the **tentacles** when stretched to their utmost may reach to a distance of two or three inches, and can be seen to move about in the water apparently in search of objects which may serve for food. The animal is capable of locomotion either by a sliding process of the base of attachment, or by the bending of the body and attachment of the tentacles followed by a change in position of the base, or the whole body may loosen from its attachment and float about in the water, coming to rest at some other point. When the tentacles come into contact with a food object such as a

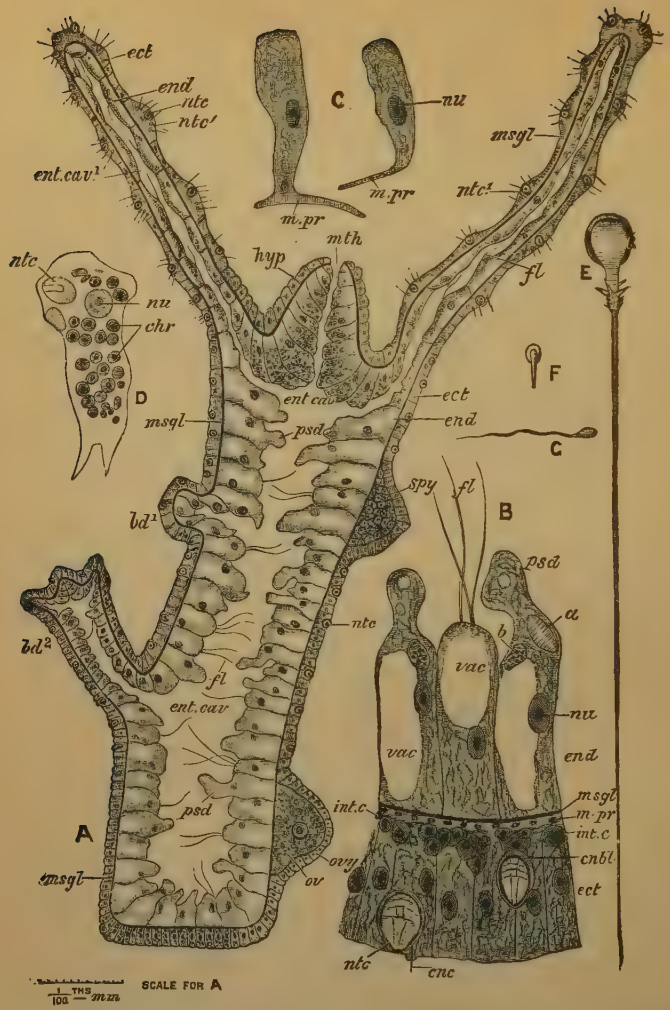


FIG. 24. — **Hydra**. A, vertical section of entire animal; B, portion of transverse section, highly magnified; C, two large ectoderm cells; D, endoderm cell of *H. viridis;* E, large nematocyst; F, small nematocyst; G, sperm; *a*, ingested diatom; *bd*[1], *bd*[2], buds; *chr*, chromatophores; *cnbl*, cnidoblast; *cnc*, cnidocil; *ect*, ectoderm; *end*, endoderm; *ent.cav*, enteric cavity; *ent. cav*[1], its prolongation into the tentacles; *fl*, flagellum; *hyp*, hypostome or manubrium; *int.c*, interstitial cells; *m.pr*, muscle processes; *mth*, mouth; *msgl*, mesoglœa; *ntc*, large, and *ntc*[1], small, nematocysts; *nu*, nucleus; *ov*, ovum; *ovy*, ovary; *psd*, pseudopods; *spy*, spermary; *vac*, vacuole. (After Parker and Haswell.)

"wiggler," or mosquito larva, the nettling cells discharge their thread-like filaments, and the larva is rendered helpless, and the tentacles close in upon it from different directions, draw it down to the mouth opening, and gradually force it through the mouth into the stomach cavity, where it is digested. After the process of digestion, the indigestible portions are forced back through the mouth opening. The general sensitiveness of the body surface can be easily determined by touching any portion of the surface, and a discharge of the nettling threads may be readily watched by placing the Hydra in a watch glass under a low-power microscope and adding to the water a drop of methylene blue, which so affects the Hydra as to cause the liberation of large numbers of the cells. Some individuals are likely to be found which show the formation of buds on the side, and if these be watched for a time, they may be seen to grow and ultimately to separate from the parent form, showing the process of reproduction by budding.

So much of the structure and habits of the animal can be readily followed with the living specimen, and, since the body is transparent, even some details of the more minute anatomy can be studied with the microscope. Careful focusing, for instance, will enable one to see the outer and inner layers of cells, the bases meeting closely on the **mesoglœa**, and this arrangement of cell layers extends into the tentacles and up to the mouth opening, the cells of the **ectoderm** and **endoderm** meeting at the margin of the mouth. More careful study with the proper preparation of material will show the ectoderm cells to include some specialized forms having an external tactile appendage and an inner muscle strand lying upon the mesoglœa. These sensitive muscle cells furnish the basis for the sensibility and contractility of the animal and may be looked upon as a very simple or primitive form of sensory and muscular structure, represented in higher forms by nervous and muscular systems. The cells of the endoderm have the function of digestion, and absorb from the food material brought into the body the nutritive substances which are used in

the growth and nutrition of different parts of the body. There is no special organ for respiration or circulation, these functions being performed by the cells in general, the oxygen being taken in from the surrounding water and nutritive substances carried by absorption to the cells surrounding the central cavity.

Reproduction is of two kinds, the more commonly observed being the method by budding already mentioned, the essential process of which is the outgrowth of a portion of the body wall carrying with it both the ectoderm and the endoderm layers; and this in time develops a series of tentacles, and forms the mouth opening on the same plan as that of the parent individual, and this is followed by a separation at the base, so that the individual becomes independent. Occasionally several individuals may retain their connection so as to appear like a colony, but ordinarily the separation occurs soon after the development of the tentacles and mouth. Sexual reproduction appears in certain individuals, and both male and female germ cells may be developed in the same individual. The female cells, or **ova**, develop in the ectoderm near the base of the attachment, while the male cells, the **spermatozoa**, arise in small masses, the **testes**, near the base of the tentacles. The ripened spermatozoa simply break away from the ectodermal layer and float about in the water, the eggs being fertilized by contact with the spermatozoa and new individuals arising from the fertilized ova.

The power of **regeneration** is very pronounced in these simple forms, so that the loss of a part is quickly replaced by the growth of new bodies, and the hydra may be cut into a number of fragments and each one reproduce a complete individual.

Order **Hydroida**. — Simple hydroid forms not forming colonies nor having free medusoid forms.

The simplest form is the fresh-water Hydra, which has been described and which with a few related forms constitutes a family called the *Hydridæ*.

Order **Hydromedusæ**. — Hydroids which have either a fixed or free-swimming habit and which develop into colonies only

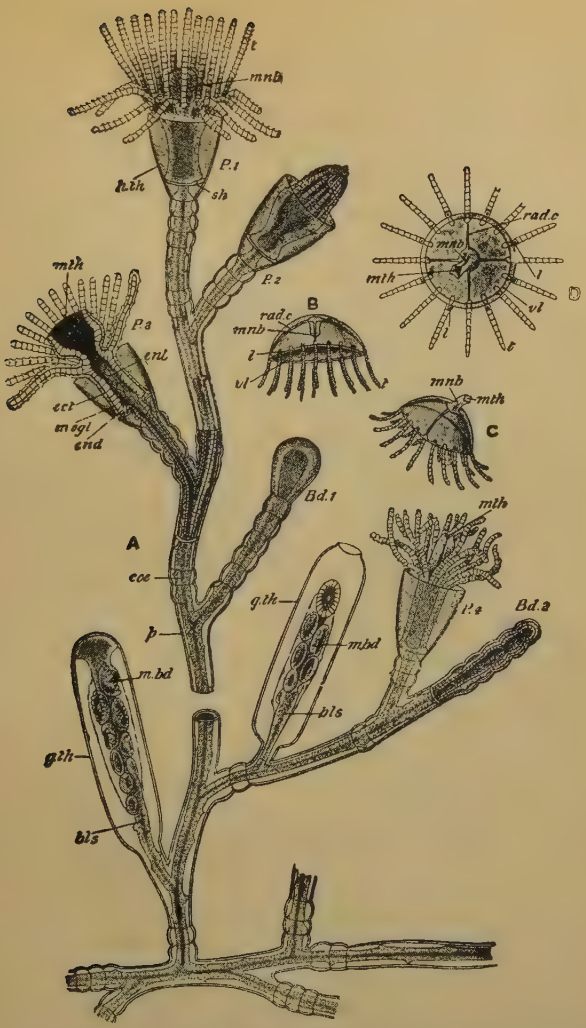


FIG. 25. — **Obelia sp.** A, portion of a colony, with certain parts shown in longitudinal section; B, medusa; C, the same, with reversed umbrella; D, the same, oral aspect; *Bd. 1, 2,* buds; *bls,* blastostyle; *cœ,* cœnosarc; *ect,* ectoderm; *end,* endoderm; *ent,* enteric cavity; *gth,* gonotheca (gonangium); *hth,* hydrotheca; *l,* lithocyst; *m.bd,* medusa bud; *mnb,* manubrium; *msgl,* mesoglœa; *mth,* mouth; *p,* perisarc; *P. 1, 2, 3, 4,* polypes; *rad.c,* radial canal; *t,* tentacle; *vl,* velum. (After Parker and Haswell.)

in the attached form. The bodies may be without hard parts, but in some cases are provided with tough, hardened or chitinous walls which may form cases within which the animal is protected. The colonial forms include frequently different types of individuals which perform different functions and which are known as **nutritive zooids, reproductive zooids,** etc., according

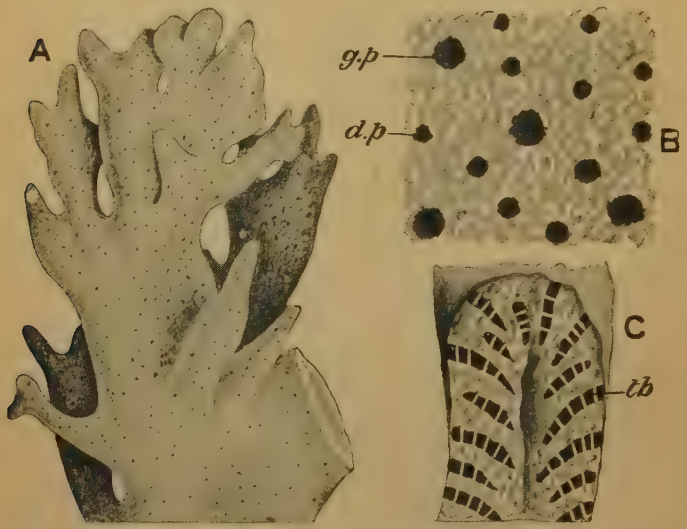


FIG. 26. — **Millepora alcicornis**. A, part of skeleton, natural size; B, portion of surface, magnified; C, vertical section magnified; *d.p*, dactylopores; *g.p*, gastropores; *tb*, tabulæ. (After Nicholson and Lydekker.)

to the function. Where the individual zooid is included in a hard covering, this may be known as **zootheca** or **gonotheca,** according as it includes the nutritive or the reproductive zooid. Where borne on a branching stem the chitinous or jointed stem is called **hydrocaulus**. Several different types are included, and the group contains in some of the animals a large number of species, many of which are very conspicuous by their abundance.

In *Hydractinia* we have forms which occur as colonies and

which include nutritive and reproductive zooids, and these occur as practically independent individuals, being simply connected by a basal structure spread out upon the rock or other object to which it is attached. The *Obelia*, representing the *Campanularidæ*, forms a many-branched colony, and the zooids are included in well-marked chitinous walls.

In *Sertularia* and its allies, forming a very extensive family, the zooids are arranged regularly on opposite sides of the central axis, some appearing like broad feathers. The zooids are very minute, and the feather-like colony sometimes has a length of several inches. *Plumularia* is somewhat similar in its general character.

In another group, the *Milleporidæ*, we have simple zooids without chitinous coverings, but they have a property of secreting lime-like material and build up structures which closely resemble the coral formations produced by the coral polyps. They differ, however, essentially in anatomy, having the simple plan of structure pertaining to the hydroids. The *Millepora* builds large brownish white fronds of lime, while the *Stylaster* builds up branching tree-like structures which have a most beautiful pink color. In both of these groups the lime-forming habit results in the building of extensive reefs, these being particularly abundant in the Caribbean and along the southern coast of Florida.

Order **Siphonophora.** Hydroids in which the base of attachment is a floating stem or an axis built up by the joint effort of the members of the colony, and a large number of individuals may in this manner be associated together in a floating colony. Connected with this is the division of labor among the different members of the colony, some remaining as simple nutritive zooids, others developing into reproductive individuals, and still others into locomotor structures, **nectocalyces**, and others undergoing a certain amount of degeneration and serving simply as protective coverings for the nutritive and reproductive forms. In such a colony as this we see the same sort of division of labor as occurs in

FIG. 27. — **Halistemma tergestinum**. A, the entire colony; B, a single group of zooids; *cœ*, cœnosarc; *dz*, dactylozooid; *hph*, hydrophyllium or bract; *nct*, nectocalyx or swimming bell; *ntc*, battery of nematocysts; *p*, polype; *pn*, pneumatophore or float; *s*, *s'*, sporocysts; *t*, tentacle. (After Claus.)

more highly integrated animals in the formation of distinct sets of organs for the performance of certain functions. The nutritive zooids correspond very closely with the ordinary attached hydroid, having the cylindrical or vase-shaped body with a simple mouth surrounded by a circle of tentacles, and the processes of food capture, digestion, and absorption are similar to those of ordinary hydroids. The nutritive materials, however, are distributed to the other members of the colony through the axial structure to which the colony is attached. The reproductive zooids resemble those of the colonial hydroids such as Hydractinia, but the **locomotory zooids** present a new type of structure, since they differ from the medusa form in that there is no mouth or digestive system in them. They are frequently arranged regularly along one end of the axis and so adjusted that by successive pulsations they eject water, and by this means force the colony along in the opposite direction. In some forms the end of the axial body, which is the forward end in most cases, is inflated into a bladder-like structure, the **pneumatophore**, which, filled with gas, serves as a float to keep the colony at or near the surface of the water. The plan of structure in these forms can better be appreciated from the figure than from any description, but it must be remembered that this exhibits only one form of colony, there being a large variety included in the group. In some cases the locomotory zooids are but one or a few, and in other cases they may consist of a large number of pairs or alternating bodies. In some, again, the pneumatophore is very much inflated, while the locomotory zooids are reduced or wanting. This occurs in the case of the Portuguese man of-war, a beautiful little object, the bladder-like float of which rests on the surface of the water and is driven by the wind as its means of locomotion. This is, perhaps, one of the first indications of a special device for taking advantage of the movements of the air to accomplish locomotion. From this pneumatophore there hang long thread-like axial cords bearing numerous zooids of the nutritive and reproductive forms. These animals have the nettling property very fully developed,

and contact with them often produces quite serious results. It is strong enough to paralyze a man's arm for a considerable length of time. None of the species has particular economic importance, but they constitute a rather conspicuous element in marine life.

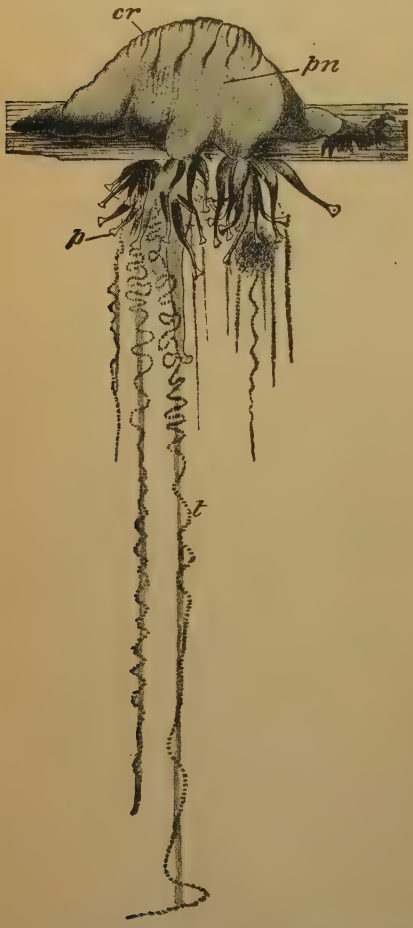


FIG. 28. — **Physalia**. The living animal floating on the surface of the sea. *cr*, crest; *p*, polype; *pn*, pneumatophore, float, or air sac. (After Huxley.)

FIG. 29. — Portuguese man of war. **Physalia arethusa**, natural size. (After Agassiz.)

Class Scyphozoa

In this group the ectoderm is infolded to form a **gullet**, into which food material is received and from which the nutritive materials are carried on into the stomach spaces. The gonads arise in the endoderm. The body is separated into divisions or chambers, which are particularly marked in the polyp by a series of partitions, or **septa**, part of which extend from the outer wall to the gullet, their margins being free from below the opening of the gullet into the digestive space, and there are frequently between these primary septa secondary or partial septa which extend from the outer wall part way to the gullet. Still others, the tertiary, may occur in the more complicated species. The relation of these septa may be seen in the general diagram showing the internal structure and cross-sections of the animal in different planes. The group includes two quite distinct divisions or subclasses; one including those which have mostly free-swimming forms, and the other including the polyps, sea anemones, etc.

Subclass Scyphomedusæ

The members of this group are commonly large gelatinous masses in the free-swimming forms termed jellyfish, indicating the texture of the object. They at times float near the surface of the water and may occur in large numbers, making a conspicuous showing along the coast, and, especially in forms which are phosphorescent, giving peculiar light to the sea water if disturbed at night. The shape of the body is quite like an umbrella or bell, the mouth being on the lower or concave side and surrounded usually by an extensive folded structure called the **manubrium**, within the base of which is the mouth opening. Around the margin of the umbrella are arranged a number of tentacles usually in multiples of four. The umbrella margin is also supplied with organs called the eyes and otocysts, which are doubtless sensory in function and which in this group are covered by a fold of the umbrella

margin, hence sometimes called the covered-eyed medusæ, as contrasted with the naked-eyed medusæ included under the Hydrozoa. The mouth opens into the digestive space, and from this radial canals branch out into different parts of the body. The gonads

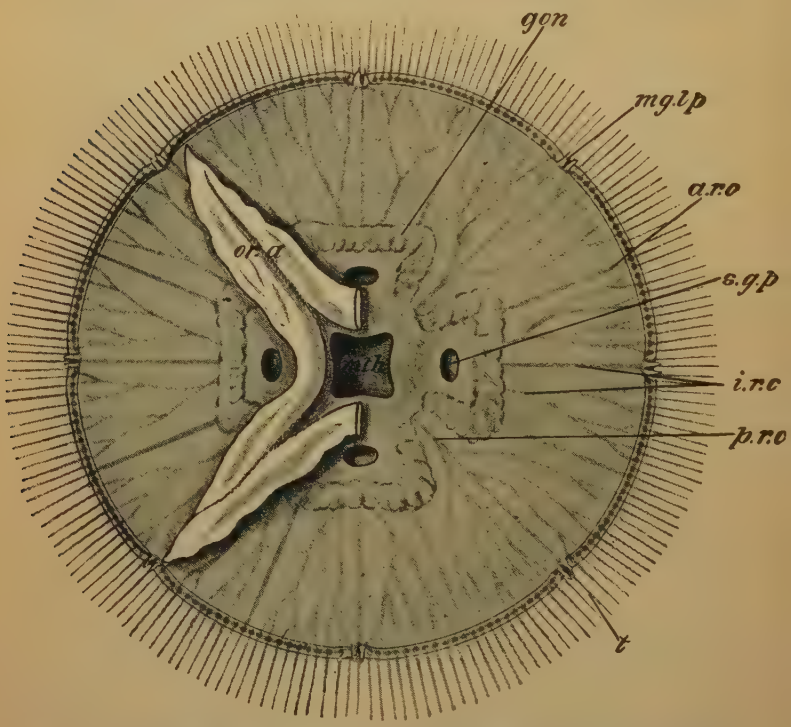


FIG. 30. — **Aurelia aurita**. Ventral view — two of the oral arms are removed. *a.r.c*, radial canal; *gon*, gonads; *i.r.c*, radial canal; *mg.lp*, marginal lappet; *mth*, mouth; *or.a*, oral arm; *p.r.c*, radial canal; *s.g.p*, sub-genital pit; *t*, tentacles. (From Parker and Haswell.)

are in the walls of the gastral pouches, the ova and sperms being discharged into the pouches and from these passing out through the mouth. The development is varied, in some forms the fertilized ova developing directly into the medusa form, and in other

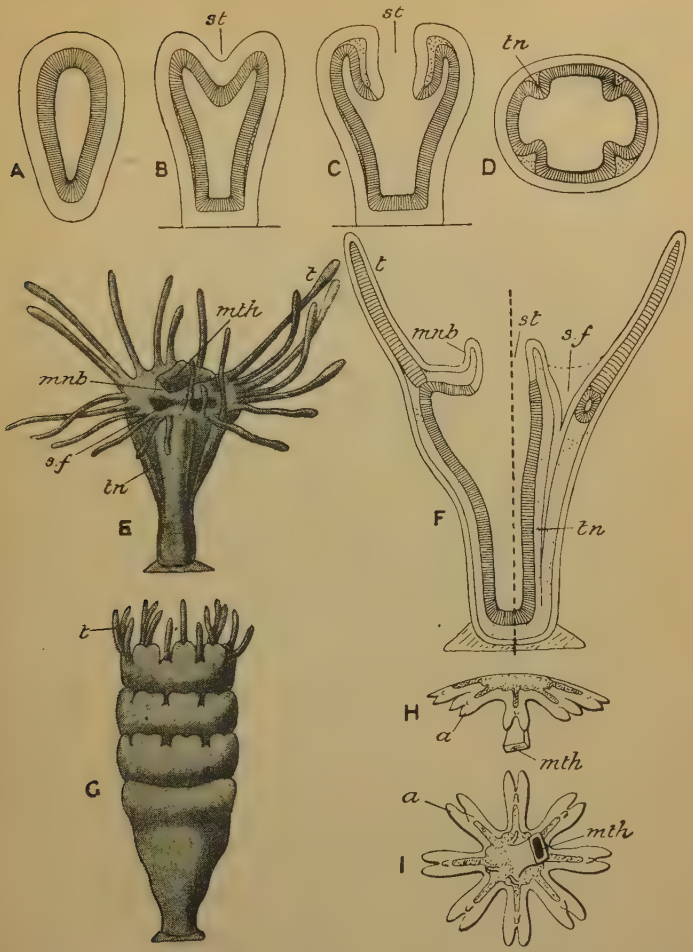


FIG. 31. — **Aurelia aurita**, development. A, planula; B, C, formation of the gullet or stomodæum; D, transverse section of young scyphula; E, scyphula; F, longitudinal section of same; G, division of scyphula into ephyrulæ; H, ephyrula from the side; I, the same from beneath. In A–D and F the ectoderm is unshaded, the endoderm striated, and the mesoglœa dotted. *a*, lobes of umbrella; *mnb*, manubrium; *mth*, mouth; *s.f*, septal funnel; *st*, stomodæum; *t*, tentacle; *tn*, tænioles, or gastric ridges. (From Korschelt and Heider's *Embryology*.)

cases the larval stage becoming fixed and passing through the hydroid-like form known here as the scyphistoma, from which in a later stage of the development there will arise a series of saucer-like structures, the ephyræ, these separating and swimming freely and developing into the adult medusæ. Some of the jellyfish acquire a very large size and have tentacles of considerable length, and since these are abundantly supplied with nettling cells, they may cause a quite serious irritation if they are handled incautiously. But little economic importance can be attached to the group, since the bodies are extremely fragile, contain no hard parts, and do not furnish any great amount of food material for other more important species. They disintegrate so rapidly that they are very poorly represented among fossils. Nevertheless some species have been recognized in the geological strata of former ages.

Subclass Anthozoa

The sea anemone and coral polyps differ from the jellyfish mainly in the fact that the polyp or attached form is the rule, and from the hydrozoan polyp in the infolding of the ectoderm to form a gullet and in the development of the septa and location of the gonads. The common sea anemone serves as a good example for the group. The body is cylindrical, attached to a broad base, and the opposite end surrounded by a large number of tubular tentacles arranged in rather definite rows around the mouth opening. The gullet extends about halfway down the center of the body and is oval in shape. The lateral folds of the gullet are termed siphonoglyphs. The septa passing from the outer wall of the gullet are provided near the upper part with an aperture which permits communication between the different chambers formed by the septa. The free septa or mesenteries bear on their margin the gonads and also the mesenterial filaments. The sea anemone in capturing its food uses the tentacles, but seems also to depend upon the production of currents by which small organisms are carried into the mouth. The nettling

cells are present in numbers and serve the same purpose as in other forms.

The sea anemones present a great variety of form, many of them being highly colored, and are conspicuous features in shallow water, especially on the reefs and rocky shoals of the ocean.

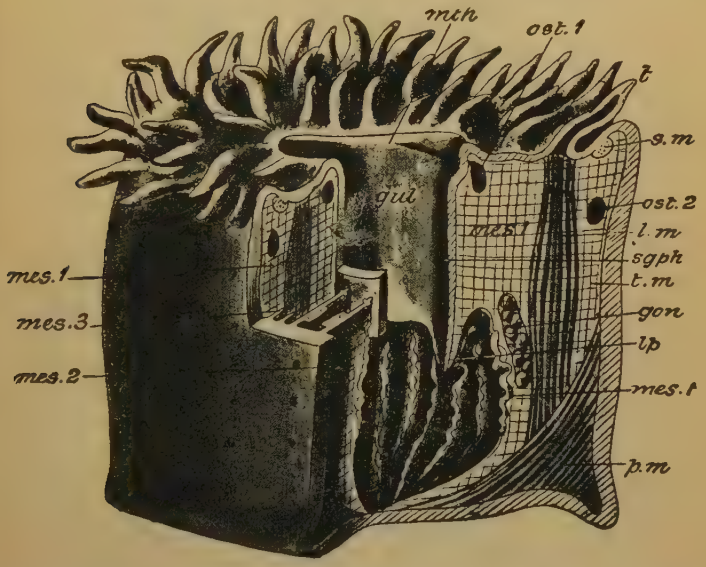


FIG. 32. — **Tealia crassicornis**. Dissected specimen; *gon*, gonads; *gul*, gullet; *l.m*, longitudinal muscle; *lp*, lappet; *mes. 1*, primary, *mes. 2*, secondary, *mes. 3*, tertiary, mesenteries; *mes.f*, mesenteric filaments; *mth*, mouth; *ost. 1*, *ost. 2*, ostia or aperture in mesenteries; *p.m*, parietal muscle; *sgph*, siphonoglyphe; *s.m*, sphincter muscle; *t.m*, transverse muscle. (After Parker and Haswell.)

Externally they have the same appearance as the coral polyp. The coral polyps have the property of secreting a limy, calcareous, or horny base, and this builds up permanent hard structures. Of the coral polyps there are two quite distinct divisions, based on the number of septa, the Hexacoralla including those forms with six septa, and the Octocoralla, those with eight. The former

group, as a whole, secrete lime and are the forms which have built up the immense layers of coral lime which form extensive reefs in the ocean at the present time and which may be found as a large part of certain rock strata formed in past ages. Immense deposits, including such coral formations, occurred in the Silurian and Devonian ages and indicate a great amount of coral life at that

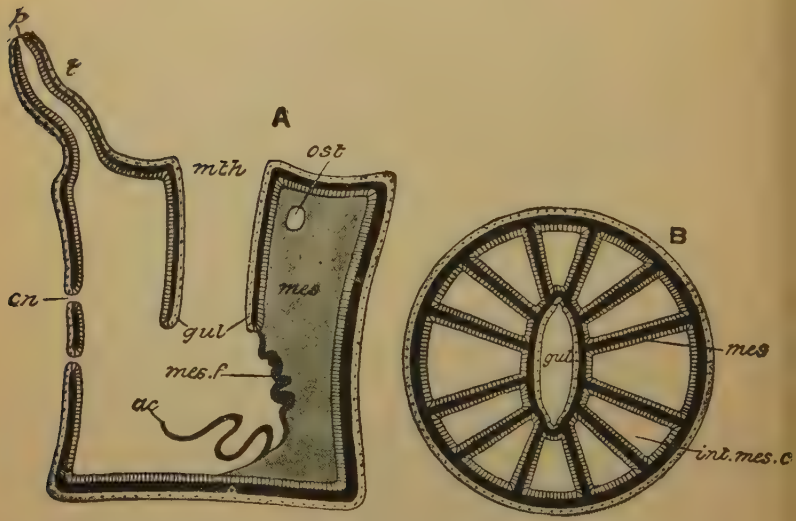


FIG. 33. — Diagrammatic vertical (A) and transverse (B) sections of a sea anemone. The ectoderm is dotted, the endoderm striated, the mesoglœa black. *ac*, acontium; *cn*, cinclis or aperture in body wall; *gul*, gullet; *int.mes.c*, intermesenteric chamber; *mes*, mesentery; *mes.f*, mesenteric filament; *mth*, mouth; *ost*, ostium; *p*, pore; *t*, tentacle. (After Parker and Haswell.)

time. This is, perhaps, the most important relation which may be assigned to this group, since many quarries of valuable limestone consist largely of the lime secreted from sea water through the agency of these forms. Furthermore, the building up of extensive reefs, some of which are very dangerous to navigation, is also of great economic and commercial importance. The relation of these reef-making animals and the formation of the coral

reef islands is one of the interesting phases in their study and has been the subject of much discussion. In some cases these reefs appear to be founded upon islands which have been slowly sink-

FIG. 34. — **Adamsia palliata**, four individuals attached to a gastropod shell inhabited by a hermit crab. *ac*, *ac*, acontia; *sh*, shell of gastropod. (After Andres.)

ing, so that the growth of reef has been kept at the surface of the water only by continued additions that keep pace with the rate of sinking. In other cases the presence of coral formations on land many feet above the water level indicates the elevation of

the land in such places. This subject, however, is usually treated more in detail in physiography or geology. The corals are exceedingly beautiful structures and are great favorites as ornaments or curiosities for museum cabinets.

FIG. 35. — Brain coral, **Meandrina labyrinthiformis**. (From photograph by H. T. Osborn.)

The octocoralla generally have a hardened base which frequently grows into an extensive branched form, the surface of the branches being covered with a corky layer, and the polyps being distributed in numbers over the surface, each one presenting the structure which has been described as common to the

members of the group. The common red coral of commerce, which has been used probably for centuries as material for ornaments in the manufacture of jewelry, has a very hard, strong,

FIG. 36. — Branching coral, **Cacropora cervicornis**. (From photograph by H. T. Osborn.)

bright red material for the axis, which takes a high polish and makes very beautiful ornaments. Other forms, such as the sea fan, the sea pen, and the organ-pipe coral, are good examples of the group.

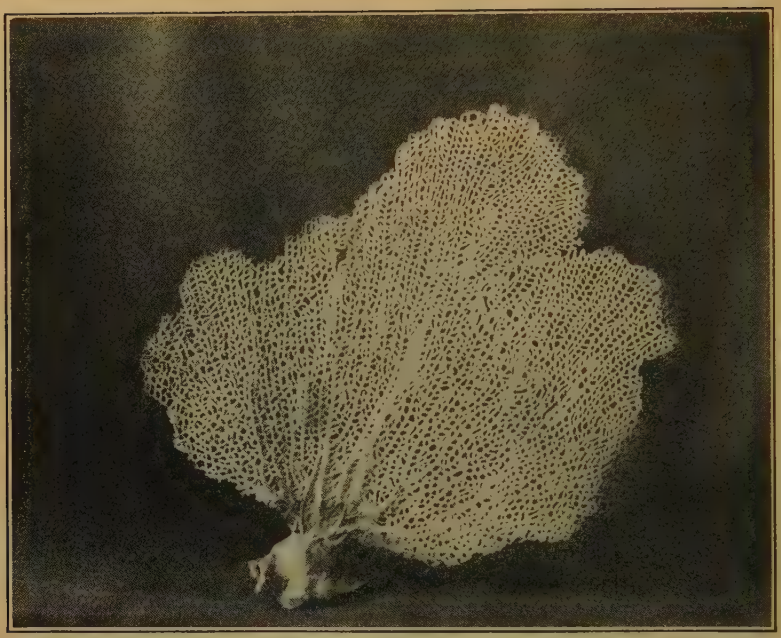


FIG. 37. — Sea fan, **Gorgonia flabellum.** (From photograph by H. T. Osborn.)

FIG. 38. — Corals on the Great Barrier Reef of Australia. (After Saville Kent.)

Class Ctenophora

These are free-swimming, delicate, usually transparent animals occurring near the surface in oceanic waters and having a rather

Fig. 39. — Various forms of limestone from modern coral formation. (Saville Kent.)

more complex structure than the other cœlenterates. They are provided with a series of comb-like plates or cilia arranged in zones on the body surface, which serve as locomotor organs.

The alimentary canal is flattened and is provided with a number of canals, one of which opens at a point on the body opposite the mouth: this seems to foreshadow the formation of the intestine and anal opening. Instead of being provided with nematocysts, we find peculiar adhesive cells distributed over the tentacles.

A very striking form is the Venus girdle, which is greatly expanded laterally and flattened so as to have the appearance of a long broad ribbon. When alive and swimming by a regular undulatory movement it reflects the colors of the spectrum in a most beautiful manner.

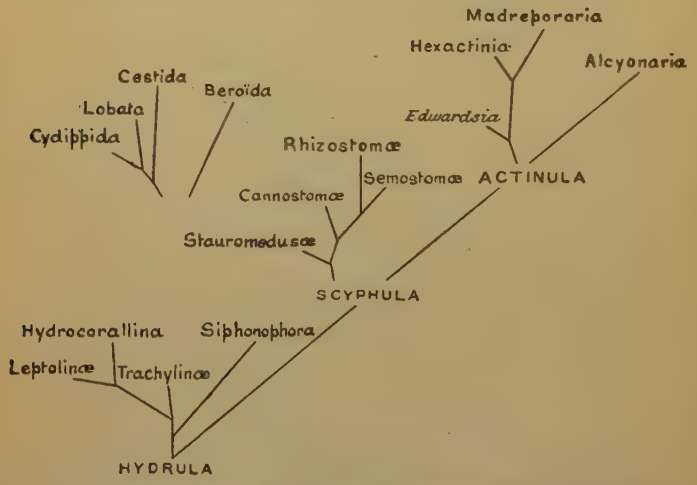


FIG. 40. — Diagram to illustrate the mutual relationships of the **Cœlenterata.** (After Parker and Haswell.)

CHAPTER IV

FLAT WORMS

Class Turbellaria

The Turbellarians are simple flattened forms representing probably about the most simple condition of animals having bilateral symmetry. They are mostly small, the common species ranging from one quarter of an inch to one half or three quarters of an inch, and they are of particular interest, inasmuch as they indicate the line of derivation for the groups of animals having bilateral symmetry.

The more common forms occur in water, and may be found under stones or adhering to objects immersed in water. The fairly common fresh-water species, *Planaria torva*, is about one half inch in length, only a little over one sixteenth of an inch wide, and quite flat. The sides are nearly parallel and the outline somewhat irregular. In moving, one end is regularly forward, and this may be considered as the anterior end. Near this end are two specks, the eye spots, which probably have some visual function, although quite certainly not able to form a distinct image. The surface of the body is ciliated and includes, in some forms, minute nettling structures, or stinging cells and cells which secrete minute rod-like bodies, the **rhabdites**. The mouth is located on the ventral side, and leads to the simple protrusible pharynx, and this through the short esophagus to an elongated stomach, but there is no posterior opening for the alimentary tract. There are no organs representing the respiratory or circulatory functions, and there is no true body cavity, but a distinct excretory system is present and consists of two canals which have numerous branches, the internal terminations of which are flame cells,

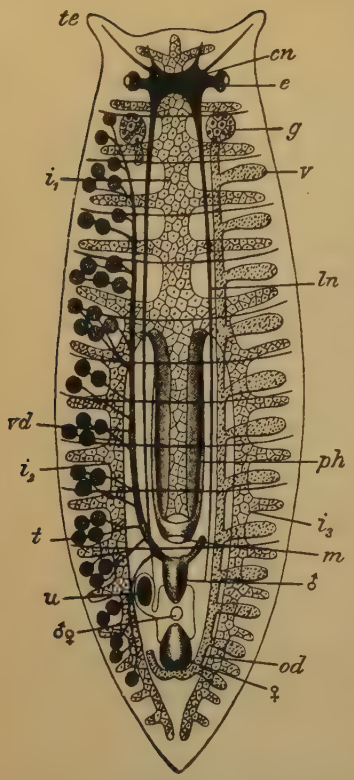


FIG. 41. — General plan of the structure of a **Triclad turbellarian**. *cn*, brain; *e*, eye; *g*, ovary; i_1, median limb of the intestine; i_2, left limb; i_3, right limb; *ln*, longitudinal nerve cord; *m*, mouth; *od*, oviduct; *ph*, pharynx; *t*, testes; *te*, tentacles; *vd*, vas deferens; *u*, uterus; ♂, ejaculatory duct; ♀, vagina; ♂♀, common genital aperture. (After Von Graff.)

and it is through these that the excreted parts are taken and carried along the lateral ducts and out of the excretory pore located near the posterior end of the body. In reproduction the two sexes are usually present in the same individual, but in many cases reproduction occurs by division of individuals, and sometimes the divided forms adhere together so as to form chains.

The Turbellarians are too minute and scarce to constitute any important economic factor, and the only thing that can be said of them in this connection is that they take some part in forming the food supply for other aquatic organisms and that they may themselves feed upon more minute organisms. A few of the species occur on land, some of these reaching a considerable size, some of the forms being a foot or more in length, but these, like the aquatic forms, have little economic importance.

The group is of especial interest, however, in that it is evidently the basis from which the Trematodes and Cestodes were derived, and as already suggested it also appears to represent the starting point for the development of the bilaterally symmetrical groups.

Class Trematoda

The Trematodes are parasitic forms, most of them occurring in the internal organs of the higher animals, a few living externally on the gills or outer parts of fishes. They are usually elongated and flattened in shape, and their bodies are devoid of cilia. Organs for attachment in the form of suckers occur in varying numbers from one to several. The mouth is at the anterior end and leads to a muscular pharynx and short esophagus, which generally branches into two or more ducts, and, in some cases, these give rise to a large number of branches, all of which end blindly, there being no distinct anal opening. Organs for circulation and respiration are wanting, but the excretory system is well developed, consisting of a large number of ducts opening internally into cavities containing delicate flame cells and connected with a longitudinal duct that opens into a pore at the posterior end of the body. The reproductive organs are rather complex, both sexes being included in the same individual. The nervous system is simple, consisting of two nerve centers adjacent to the esophagus, from which nerves pass both forward and backward to supply the different parts of the body. One of the most important species and one which furnishes a most excellent example of the results of parasitism in these forms is the common liver fluke affecting sheep. This may be taken as the type of the group.

The Liver Fluke of the Sheep. — This destructive parasite of the sheep is also an extremely interesting species in its life history, since it must necessarily alternate between a mammal, usually the sheep, and a mollusk, an aquatic snail, in completing its life cycle. It produces a disease known as liver rot because the liver, which is the affected part, will, when invaded by a number of parasites, become inactive, the tissues degenerate, and the effect upon the sheep often proves fatal.

While this form has never been remarkably plentiful in the United States, a sufficient number of cases is on record to show that it must be taken into account in the sheep industry, and

precaution observed so that it may not reach such destructive prevalence as in the Old World. It is stated that at one time in a certain portion of England the loss from this species was something like three million head of sheep annually, and, indeed, the

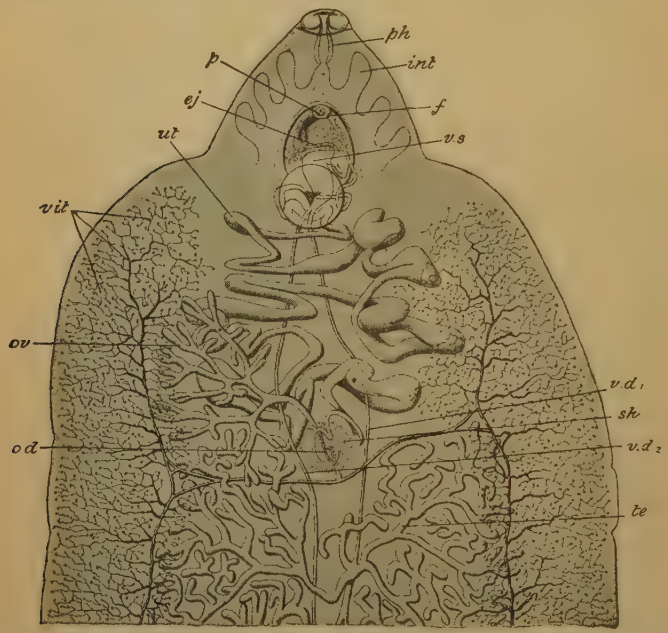


Fig. 42. — Distomum hepaticum. Internal organization. General view of the anterior portion of the body, showing the various systems of organs as seen from the ventral aspect. *ej*, ejaculatory duct; *f*, female reproductive aperture; *int*, anterior portion of the intestine (the rest is not shown); *od*, commencement of oviduct; *ov*, ovary; *p*, penis; *ph*, pharynx; *sh*, shell gland; *te*, testes; *ut*, uterus; vd_1, left vas deferens; vd_2, right vas deferens; *vit*, lobes of vitelline glands; *vs*, vesicula seminalis. (After Sommer.)

enormous loss from this parasite in England and Germany was the principal reason for the investigation of its life history, which revealed the necessary cycle between the sheep and the snail and made it possible to adopt the measures by which its destructive attacks may be entirely prevented.

The adult fluke, the form occurring in a sheep's liver, is flattened, about three quarters of an inch long, the body widening for about one fourth of its length and then tapering somewhat gradually to the tail end. There are two prominent suckers, one surrounding the mouth and the other about one quarter of the distance from the head on the under side. They serve as a means of attachment for the parasite. The surface of the body is smooth. The color is dark brown or liver colored. Each individual is capable of producing something like five hundred thousand eggs, these being retained for a time in the uterus near the head end of the body. The eggs are oval, very minute, .13–.14 of a millimeter long and from .07–.09 of a millimeter wide. The eggs are discharged into the bile duct of the sheep, and from it pass with the contents of the duct into the alimentary canal, from which they are carried with the excrement so that they fall to earth and must here await proper conditions of moisture and temperature for their further development. The development of the eggs has already proceeded to some extent, but is retarded, and proceeds only after acquisition of moisture, and the larvæ hatch out at the end of probably four to six weeks if conditions are favorable. This must occur in water or the larva has no chance of survival. The larva, when hatched, is elongated in form, the head end conical, the surface covered with fine cilia which enable it to move rapidly in the water, and there is a sensory organ called the "eye spot." The active, free-swimming stage of the larva is a very critical one in its history, as it is able to survive in the active, rapidly moving condition for from eight to ten or twelve hours only, and during this time it must come into contact with a snail, or it is doomed to perish. If it succeeds in finding a snail, it takes on a rotary motion due to the action of the cilia, and the conical, pointed end of the body is gradually forced into the tissue of its future host. While doubtless able to perforate a snail at any of the soft portions of the body, it probably enters most readily through the lung cavity, and it is in the tissue surrounding the lungs that it is said to occur most frequently. There appears to

be a distinct limitation in the kind of host that it may survive in, the species serving as its host in Europe being *Lymnæa minuta-*

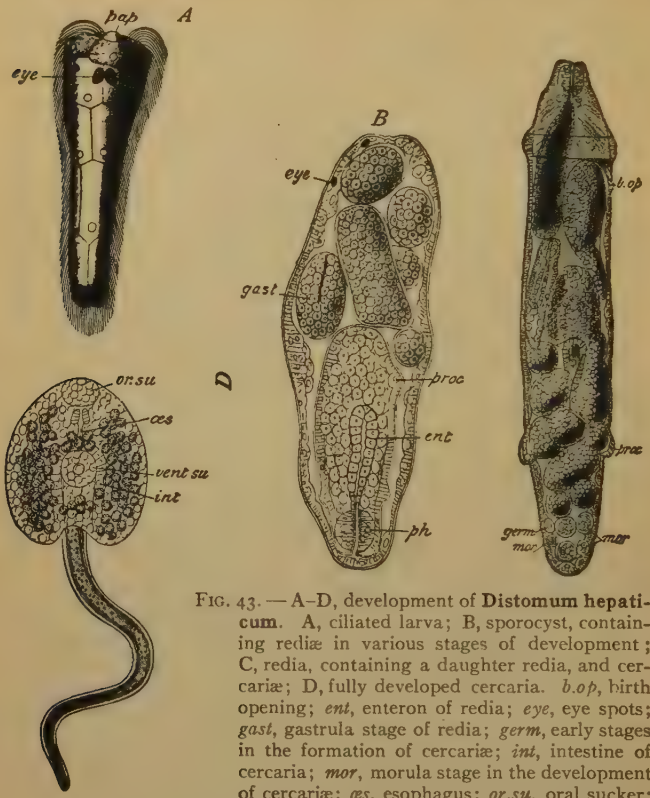


FIG. 43. — A–D, development of **Distomum hepaticum**. A, ciliated larva; B, sporocyst, containing rediæ in various stages of development; C, redia, containing a daughter redia, and cercariæ; D, fully developed cercaria. *b.op*, birth opening; *ent*, enteron of redia; *eye*, eye spots; *gast*, gastrula stage of redia; *germ*, early stages in the formation of cercariæ; *int*, intestine of cercaria; *mor*, morula stage in the development of cercariæ; *œs*, esophagus; *or.su*, oral sucker; *pap*, head lobe of ciliated embryo; *ph*, pharynx; *proc*, processes of redia; *vent.su*, ventral (posterior) sucker. (After Thomas.)

truncatula, and its host in this country is thought to be *Lymnæa humilis*.

Within the snail there is a rapid change in the larva, the form becoming more oval, the cilia disappearing, and a sporocyst results. This sporocyst may by simple division produce two indi-

viduals, and these produce within themselves elongated bodies composed of numerous cells that develop into the rediæ. A number of these may be produced within each sporocyst, and as they mature, they issue from the sporocyst and migrate in the tissues of the snail, locating most abundantly in the liver, which occurs in the upper protected part of the spiral. These rediæ, again, produce other rediæ, until a large number of these sac-like forms have resulted and the tissues of the snail become gorged with their numbers. Finally the rediæ give rise to still another form, called the Cercaria, which possesses a heart-shaped anterior end portion and a flexible tail, and in this shape the parasites issue from the snail host and wriggle about in the water, or, if the snail has been creeping on land, creep about on the vegetation with which they come into contact. Either in the water or on the vegetation they change rapidly from the motile condition into encysted forms, the cyst being attached to the stems of the plants or vegetation against which they have rested. The cercaria shows more complex structure than the redia possesses — instead of the simple alimentary canal a forked intestine, and on the outside two rudiments of suckers which later develop into the suckers of the adults. There is an absorption or disappearance of the tail, and the animal begins to assume the form of the adult fluke.

If now the cysts are swallowed by a sheep or other herbivorous animal, either by drinking the water in which the cysts floated or by eating herbage in pastures which have been overrun by snails, the limy cyst is broken down in the stomach by the action of the gastric juices, the young fluke is set free, and proceeds to work its way from the stomach into the duodenum, and by way of the bile duct to the liver. Arrived at this location, the young fluke has simply to imbed itself in the liver tissues and grow to complete the life cycle and bring us to the point from which we started in this peculiar history.

It will be noted that this cycle is fraught with dangers at many points: the eggs may fail to reach water or conditions for their hatching. If hatched, the larvæ may fail to find suitable hosts,

and if one is found, their life becomes dependent upon this single animal, and if it should happen to be eaten by a duck or other aquatic animal, the career of both host and parasite will be cut short. Still further, the cercariæ on issuing from the host snail are liable to fall prey to various minute aquatic animals, and if they become ready for the transfer to the stomach, the chance of any particular cyst being swallowed is very small.

It will be seen therefore that the enormous number of eggs produced and the great possibility of increase of individuals within the host snail by the formation of rediæ is only an offset to the enormous risks which are run by the individual flukes. Furthermore, it is evident from our knowledge of the life cycle that this parasite is absolutely dependent upon two different animals for hosts, and not only must it be dependent for existence upon the occurrence in any locality of these two host animals, but upon the special conditions which permit of its transfer from one to the other and the development within each.

Knowing this as a basis, it becomes easily possible to prevent the infection of sheep by pasturing them in land not subject to overflow and not overrun by snails, and limiting the supply of water for the sheep to wells and springs which are not occupied by snails, or, at least, into which the eggs could not be carried so as to permit the infection of the snails that might exist there. No direct remedies that are of any real service have been suggested for the treatment of the infected sheep. If the number of flukes is small, the sheep may recover; but if numerous, the infection is pretty sure to be fatal. Care should be taken in introducing sheep from other localities to keep them for the first season at least away from low ground, so that in case they are infected the chance of establishing the parasite in the locality may be avoided.

Among the other members of this group one of the most conspicuous is the giant fluke that is frequently found in the liver of deer or cattle in the Southwestern States. This is at times so plentiful in some parts of Texas as to prove a serious pest to the cattle industry. It was in all probability, before the introduction

of cattle, a native species affecting the liver of deer and other wild ruminants, and the larva stages are passed in some of our aquatic mollusks. The full life history, however, has not been followed yet, but by analogy it may be assumed that one of the best means of avoiding damage from this species will be to guard against the feeding of cattle on low land which might be overrun with snails, or by guarding the water supply as in the case of the liver fluke in sheep.

One of the species is a common parasite of ducks, and in this case the mode of transfer is clear, as ducks in feeding upon aquatic snails would infest themselves with the immature stages; but even if these escape and attach themselves to the aquatic vegetation, they would be readily swallowed by the birds in their eating.

Some of the external species are quite interesting in their means of attachment, one species being provided with as many as six large suckers, which must serve to give it a very strong hold on the host animal. The parasitic habit in these forms seems very evidently to be traced through the semi-parasitic forms and to indicate that their origin must have been in some free-living turbellarian-like form which began by attaching itself temporarily to fishes or other aquatic animals and became more and more dependent upon the host form and developed in more specialized ways in the adaptation to the life of the host forms, those which are terrestrial as well as aquatic.

The group is classified mainly on the basis of the character of the suckers and of the development. The first order includes those with the adhesive posterior organ, mostly external parasites and associated only with one host. In this division are included forms affecting the frog, gills of fishes, etc. In the second group there is a large sucker covering most of the under side of the body and including forms infesting the mollusks. In the third order there are only two suckers, or one, and there is a complicated life history with two hosts, an alternation between which is necessary for the completion of the life cycle. In most cases the adult form occurs in the alimentary tract of the vertebrates

and the larval stages in invertebrates, especially mollusks. In this group are included the liver flukes, blood flukes of Africa, and the species occurring in ducks.

Class Cestoda

The members of this group are commonly termed tapeworms and are examples of a very extreme parasitic form, the species being confined to certain kinds of animals, and their existence being wholly dependent upon such hosts; but they may occupy very different locations, some occurring in the alimentary tract, others in the abdominal cavity, and others in other tissues of the body, the most common condition, however, being for the adult or the reproductive stage to occur in the alimentary canal of the host animal. The species are apparently segmented, and the so-called segments are practically independent of each other and each one is in some sort a complete individual as far as reproduction is concerned, and hence the term "segmentation" is inappropriate. The different members are termed **proglottides**, and when fully matured each one contains a fully developed reproductive system, including both male and female organs. The worm is attached by the head, or **scolex**, which consists of a slightly enlarged end provided with suckers and, often, hooks which enable it to hold to the host animal. This is followed by a series of minute segments, the point at which additional segments are interpolated, while farther back from the head the segments gradually increase in size and change in form until the fully mature ones are reached.

One of the common species is the human tapeworm, *Tænia solium*, which occurs in the adult form in the human intestine and in the immature stage in the flesh of swine. The life cycle of this species will serve as an example of the class, illustrating the importance of migration and the stages of existence that are passed. The adult form reaches a length of twenty-five to thirty feet, and may consist of several hundred proglottides. It matures beyond about the five hundredth, and the terminal ones, when ready to separate from the chain, include the eggs. As these

Fig. 45. — Head of **Tænia solium**, magnified. (After Leuckart.)

break off and are carried out of the alimentary tract of the host the eggs are passing through the earlier stages of development, and at the time when they may be swallowed by swine are sufficiently mature to be ready to commence their burrowing through the walls of the alimentary tract and into the tissues in which they make their future home. They come to rest in the muscles, and as they grow form a distinct cyst, within which they reach a certain stage of growth; at this time they are large enough to be readily seen, and pork including them will have a spotted appearance and is termed "measly" pork. In this encysted form they may survive for a considerable period until the animal is killed, and when its flesh is eaten without being cooked they may attach themselves and form the base of development of another chain of proglottides. The encysted form or cysticercus is a sac-like structure and is the future head of the tapeworm and is invaginated, and this, when the cyst is

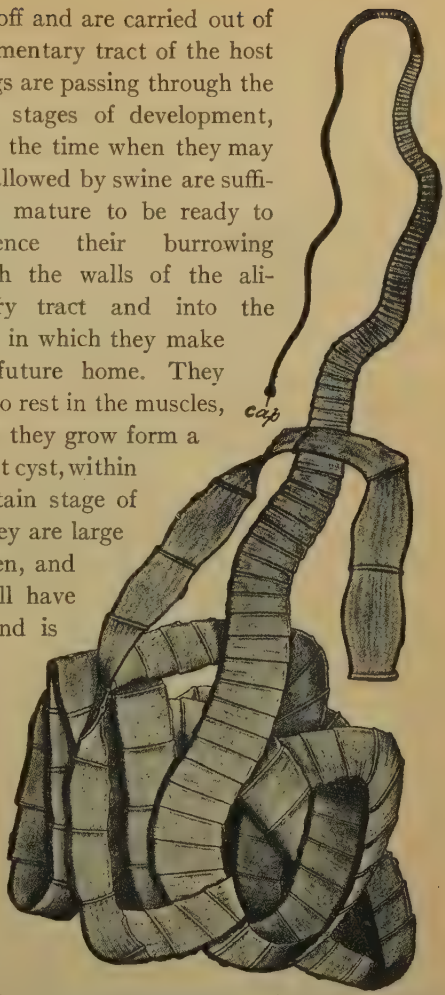


Fig. 44. — **Tænia solium.** Human tapeworm. Entire specimen reduced. *cap*, head. (After Leuckart.)

swallowed by the future host, is pushed out and the hooks and suckers extended so that they may form their attachment to the alimentary canal. It will be seen from this cycle that the life of the parasite is dependent upon a large number of conditions and that the chances of the survival of the egg are extremely small. It has been estimated, in fact, that only one out of three millions is likely to reach the adult stage. It is also shown that the one necessary condition for the prevention of infestation by these parasites is that infested pork is to be rejected, or if the infesta-

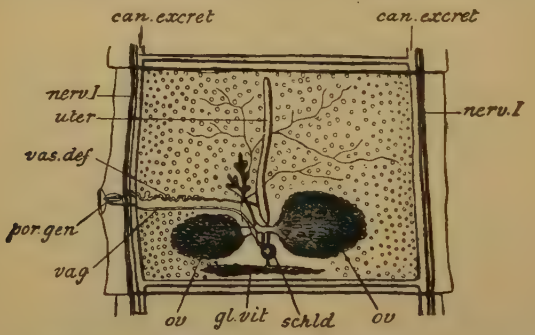


FIG. 46. — A proglottis of **Tænia solium** with mature reproductive apparatus. *can.excret*, longitudinal excretory canals with transverse connecting vessels; *gl.vit*, vitelline glands; *nerv.l*, longitudinal nerves; *ov*, *ov*, ovaries; *por.gen*, genital pore; *schld*, shell glands; *uter*, uterus; *vag*, vagina; *vas.def*, vas deferens. The numerous small round bodies are the lobes of the testes. (After Leuckart.)

tion is not evident, that it should be so thoroughly cooked that no chance is left for any living encysted forms to be swallowed.

At present the more common tapeworm in the United States is supposed to be the one derived from the beef measle. The species is very similar to the preceding one, but the larval form of this is found in cattle. The adult form is similar in size and general appearance to the *Tænia solium*, but the head end is depressed instead of convex at the extremity, and the hooks, which are conspicuous in that species, are wanting. There is also a difference in the structure of the proglottides, but this is not easily seen without special preparation for microscopic study.

The *Tænia echinococcus* is an important species in some countries, causing a high percentage of mortality. The adult form occurs in the dog, being attached in the alimentary canal, and differs from other species in being composed of four segments, the

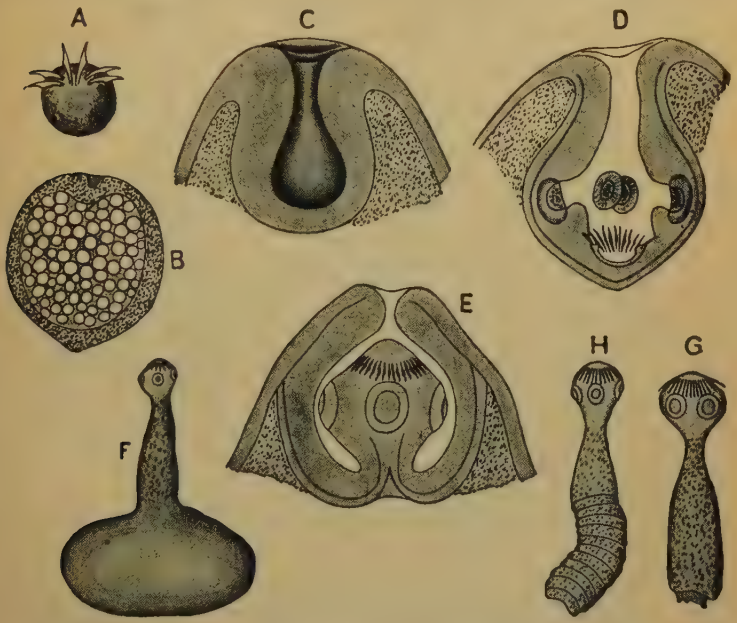
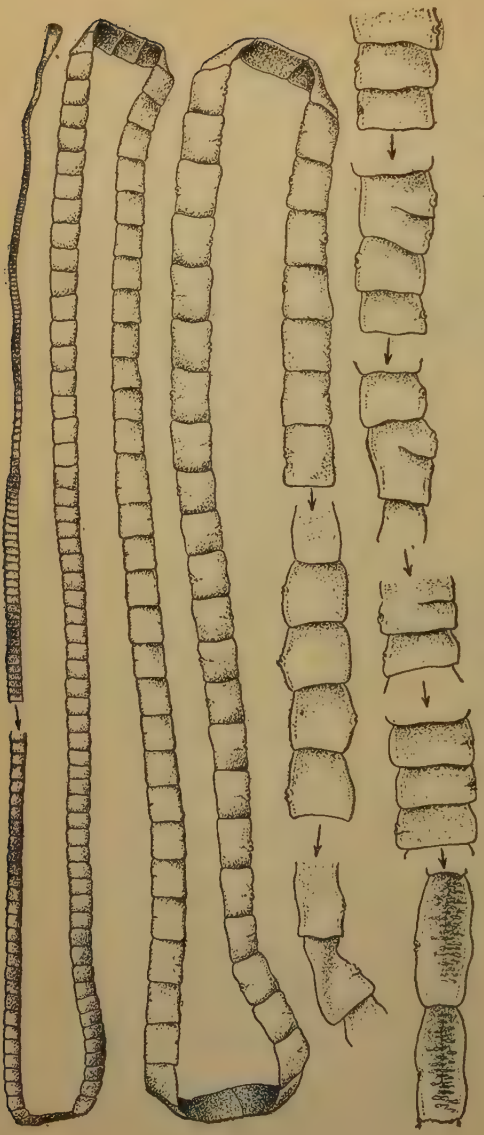


FIG. 47. — Development of **Tapeworm.** A, hexacanth embryo; B, Proscolex of *Tænia saginata;* C–E, stages in the formation of the scolex of the same; C, the invagination before the hooks and suckers have become developed; D, after the appearance of the hooks and suckers; E, partly evaginated; F, fully evaginated scolex of *T. solium* with caudal vesicle; G, scolex of *T. serrata* with the remains of the vesicle; H, young tapeworm of *T. serrata.* (After Leuckart.)

terminal one only being mature. In the larval stage it occurs in man as the bladder worms, developing into large saccular bodies, the hydatides of physicians, which, when they grow where they crowd upon important organs, are liable to cause very serious disturbances, and if they lodge in the brain, the result is commonly fatal, or at least the infection results in extreme forms of disorder.



The mode of transference for this species is doubtless mainly by the ingestion of larvæ in water or in uncooked vegetable food, as the eggs scattered by dogs may gain entrance to water or become attached to vegetation. The infection of dogs seems to be less easily accounted for, as in civilized countries the chances for dogs to feed on human flesh must be extremely rare, and it is probable that their infection comes from eating the flesh of other animals which may serve also as hosts

FIG. 48. — Several portions of an adult beef-measle tapeworm (**Tænia saginata**) from man, showing the head on the anterior end and the gradual increase in size of the segments, natural size. (Bur. An. Ind.)

for the larval form. Precautions in keeping dogs free from these parasites and also in regard to water and food or the fondling and kissing of pet dogs will serve to prevent the infection of the human species.

Another species, *Cœnurus*, that has considerable economic importance alternates between the dog and sheep, occurring as a

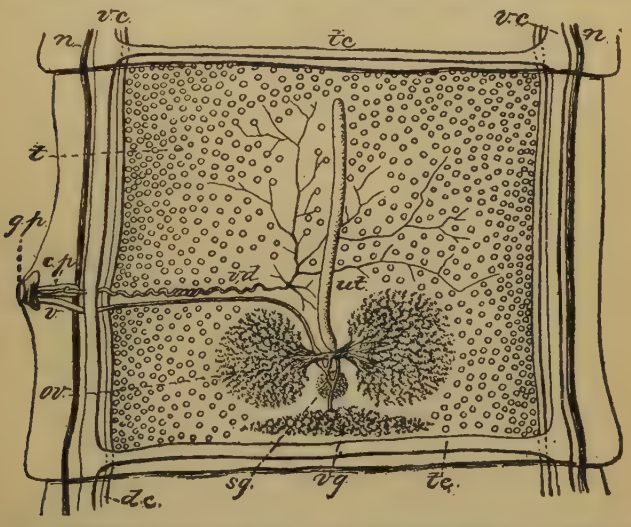


FIG. 49. — Sexually mature segment of beef-measle tapeworm (**Tænia saginata**). *c.p*, cirrus pouch; *d.c*, dorsal canal; *g.p*, genital pore; *n*, lateral longitudinal nerves; *ov*, ovary; *sg*, shell gland; *t*, testicles; *ut*, median uterine stem; *v*, vagina; *v.c*, ventral canal, connected by transverse canal, *tc*; *vd*, vas deferens; *vg*, vitellogene gland, enlarged (in part after Leuckart, Bur. An. Ind., U. S. Dep. Ag.)

many-jointed tapeworm in the alimentary canal of the dog and as a large bladder worm in sheep, affecting very commonly the brain and causing a disease known as gid or staggers. The cystic form produces a large number of scolices by the invaginations of the cystic wall, and the cyst may attain a size of one half inch or more in diameter and occupy considerable space in the brain. The transfer in this species is traced easily, since dogs in feeding upon parts of dead sheep may become infected, and they in turn

when infested with the adult tapeworm may scatter the eggs widely over the pastures in which the sheep are kept and from which the sheep may become easily infested in securing their pasturage. Evidently separation of dogs from sheep pastures or the careful extermination of tapeworms in those which are utilized in sheep husbandry, and, further, the prompt destruction of

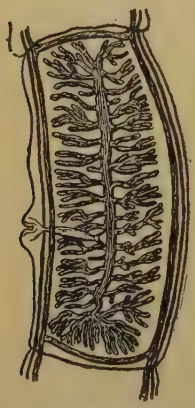


FIG. 50. — Gravid segment of beef-measle tapeworm (**Tænia saginata**), showing lateral branches of the uterus, enlarged. (Bur. An. Ind., U. S. Dep. Ag.)

FIG. 51. — Adult hydatid tapeworm (**Tænia echinococcus**), enlarged. (After Leuckart, from Bur. An. Ind., U. S. Dep. Ag.)

carcasses of sheep so that dogs may not feed upon any portions of them, will serve to eliminate this disease.

Another familiar form having a quite similar life cycle is found as an alternate parasite in the dog and rabbit, the adult form occurring in the dog and the cystic form in the rabbit. In this case it occupies the abdominal cavity, being found especially in the peritoneum, in the mesenteries, and on the surface of the liver. The cysts are large and are of course very evidently swallowed by dogs when they capture and feed upon the rabbits; the eggs develop into the adult form in the dog and are scattered in

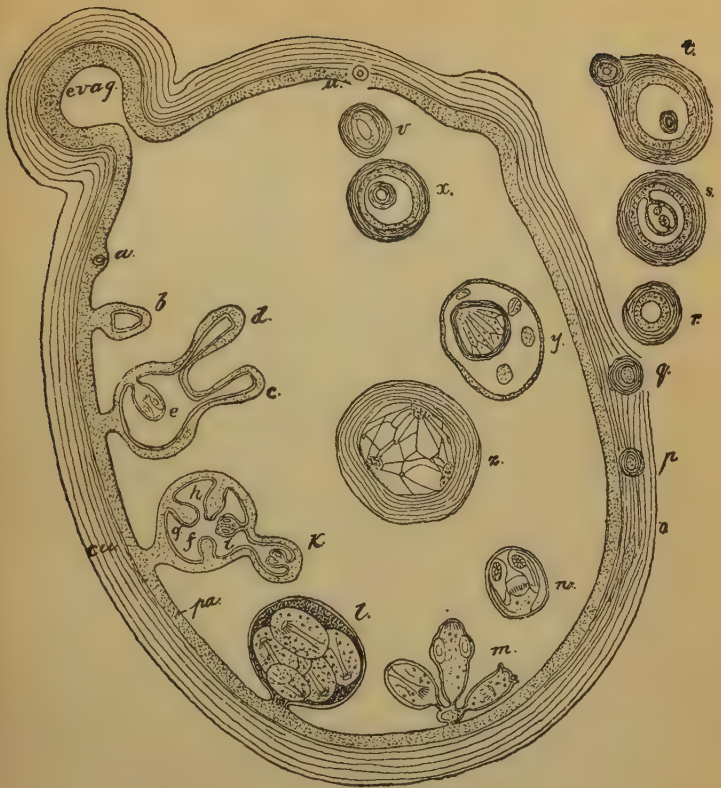


FIG. 52. — Diagram of an **Echinococcus** hydatid. *cu*, thick external cuticle; *pa*, parenchym (germinal) layer; *c*, *d*, *e*, development of the heads, according to Leuckart; *f*, *g*, *h*, *i*, *k*, development of the heads according to Moniez; *l*, fully developed brood capsule with heads; *m*, brood capsule has ruptured, and the heads hang into the lumen of the hydatid; *n*, liberated head floating in the hydatid; *o*, *p*, *q*, *r*, *s*, mode of formation of secondary exogenous daughter cyst; *u*, *v*, *x*, formation of endogenous cyst, after Kuhn and Davaine; *t*, daughter cyst with one endogenous and one exogenous granddaughter cyst; *y*, *z*, formation of endogenous daughter cysts, after Naunyn and Leuckart, — *y*, at the expense of a head; *z*, from a brood capsule; *evag.*, constricted portion of the mother cyst. (After R. Blanchard, slightly modified. Bur. An. Ind., U. S. Dep. Ag.)

the fields and distributed on vegetation on which the rabbits feed. The species, however, is of little economic importance because of the fact that while it may be injurious to rabbits, these are usually of little value, and the effect of the parasite on the dog is not ordinarily considered to be of much importance.

FIG. 53. — An adult gid tapeworm (**Tænia cœnurus**), natural size. (After Railliet, from Bur. An. Ind.)

It may be noted, however, that the dog serves as an intermediate host for a number of parasites which have an immense importance in their attacks upon domestic animals or man, and hence dogs should be kept scrupulously free from them.

A species, the life cycle of which was for a time extremely puzzling, occurs in the dog and has as its intermediate host an external parasite, the louse or flea, which occurs on the dog. In this case the licking and biting of its skin by the dog must serve as the means of introduction into its alimentary canal.

Other species affect the cat and various other mammals, and there are many species found in the shore birds, snipe, etc., which are of considerable interest, though not of course of as great importance as the ones affecting domestic animals.

Horses and cattle and sheep are infested with certain adult tapeworms occurring in the alimentary canal, which must cause

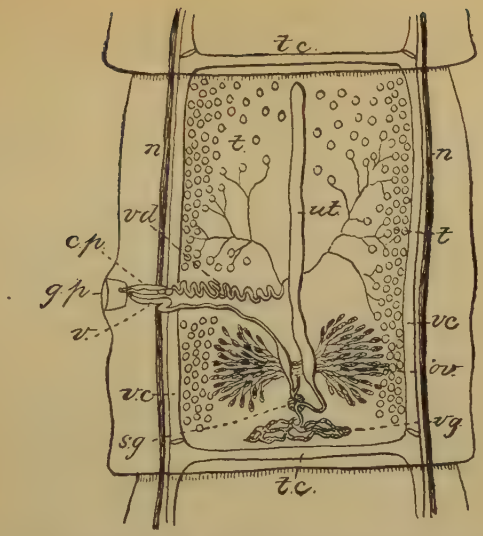


FIG. 54. — Sexually mature segment of the gid tapeworm (**Tænia cœnurus**). *c.p*, cirrus pouch; *g.p*, genital pore; *n*, nerve; *ov*, ovary; *s.g*, shell gland; *t*, testicles; *t.c*, transverse canal; *ut*, uterus; *v*, vagina; *vc*, ventral canal; *v.d*, vas deferens; *vg*, vitellogene gland. ×20. (After Deffke, from Bur. An. Ind., U. S. Dep. Ag.)

a considerable amount of disturbance but for which as yet the larval stages are unknown. It seems probable that such larval stages must occur in some intermediate host, but efforts to determine such a host have been unsuccessful.

One other species may, perhaps, be considered, since it shows a different mode of alternation between hosts and is in some

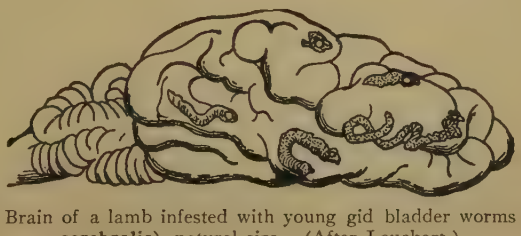
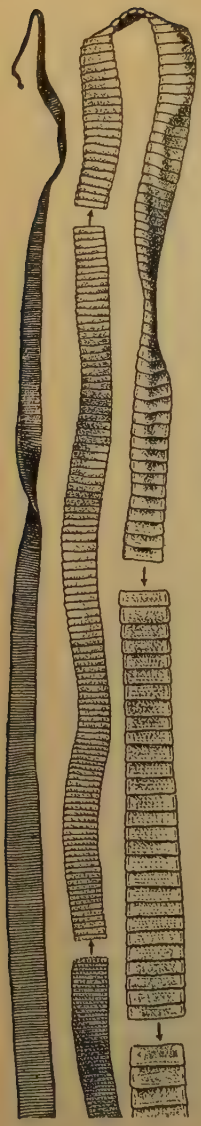


FIG. 55. — Brain of a lamb infested with young gid bladder worms (**Cœnurus cerebralis**), natural size. (After Leuckart.)



localities of considerable importance. This is the *Bothriocephalus latus*, which as an adult occurs in the alimentary canal of man and which is found in the larval stage in the flesh of fishes. In this case the eggs must be distributed in water by means of sewage. On being taken into the fish they migrate into the muscles, where they become encysted in the same manner as the beef or pork measle. If the fish are eaten dried or smoked and not thoroughly cooked so as to kill the parasite, infection of persons eating the fish may readily occur. Through careful attention to thorough cooking, or, what is better, the treatment of sewage so that there can be no contamination of the water from which the fish are derived, infection from this form might be prevented.

Effects of Parasitism

Aside from the effect which parasites have on the animals on which they live there is an exceedingly interesting question concerning the effects of the parasitic habit on the parasites themselves. We find in a great many of the parasitic animals a distinct loss of structure and a reduction of the parts which are necessary for the active existence of the non-parasitic forms. That such organs have been gradually lost or have suffered reduction as a result of the parasitic habit, is certainly strongly indicated if not posi-

Fig. 56. — Portions of an adult specimen of the broad moniezia (**Moniezia expansa**), natural size. (After Stiles and Hassall, B. A. I., U. S. Dep. Ag.)

tively proven by the evidence shown in the development of the parasitic form. In many of these, and in fact in nearly all of them which have been studied, the development shows a period in early life in which the organs of locomotion are distinctly evident but become reduced or fail to develop as the animal matures. Scarcely any other interpretation of this can be conceived than that it means the gradual loss and reduction of such organs in consequence of the parasitic life. Further, by comparison of the different species in the parasitic groups we find all gradations from non-parasitic or slightly parasitic, scarcely modified forms to those which are extreme in the

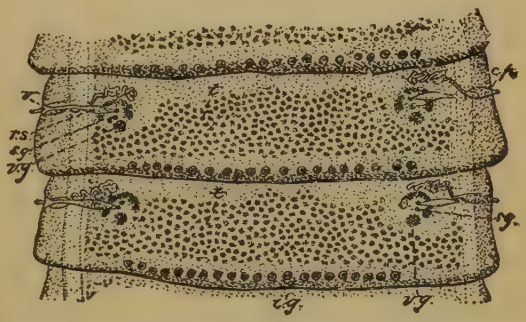


FIG. 57. — Sexually mature segments of the broad moniezia (**Moniezia expansa**). *c.p*, cirrus pouch; *i.g*, interproglottidal glands; *r.s*, receptaculum seminis; *s.g*, shell gland; *t*, testicles; *v*, vagina; *v.g*, vitellogene gland. Enlarged. (After Stiles, B. A. I., U. S. Dep. Ag.)

parasitic habit and which show the most profound changes of structure and loss of organs. It seems reasonable to conclude, therefore, that the parasitic groups have all been derived from free-living non-parasitic forms and that the habit of parasitism became more and more fixed and has produced more and more profound changes in the lapse of time. Such parasitic groups as the flukes and tapeworms and thread worms, and also the parasitic mites or insects, all give evidence in the same direction, and while their parasitic habit must have been developed on entirely independent lines, and may be connected

with entirely different forms of hosts, there is one evident story for all.

These points have a distinct significance in connection with the problems of evolution, since they show in a very marked degree the conditions of modification and, in some cases, the steps in the evolution. We can certainly conclude that the parasites of such recent animals as birds and mammals could not have existed as parasites upon these animals until the host forms were in existence, and, inasmuch as there are many cases where the parasite is strictly dependent upon a single form of host, we must conclude that its adaptation to that host has become so complete that its existence in any other condition is impossible.

The effects of parasitism have their significance in connection with the possible progressive formation of different kinds of animals. It is probable that the habit which involves loss of structure tends to become intensified and that the parasite becomes more and more limited in its habit and more completely shut off from any possible evolution into a more highly organized form. That is, when once the parasitic habit is assumed, the tendency is for it to become more and more pronounced, and the return to a free and independent form is practically impossible.

Class Nemertea

This group of organisms is pretty well separated from the other forms and presents certain marks of advancement over any of the other groups hitherto considered, especially in the alimentary tract and the proboscis. They are somewhat flattened, elongated, worm-like, with no apparent segmentation. The species are mainly marine and carnivorous in habit.

A quite remarkable feature in their structure is the presence of a protrusible proboscis lying above the alimentary tract but not connected with it, and forming a distinct protractile organ, which is also used as a weapon in defense. The nervous system is peculiar to the group. The ganglia in the anterior end lie at the sides of the esophagus and are connected by commissure, while

two strong lateral nerve cords extend from these ganglia to the posterior end of the body, where they connect above the alimentary tract. The alimentary canal opens anteriorly and is surrounded by cilia. The pharynx and esophagus broaden into an elongated stomach, the size of which varies a little, and tapers gradually posteriorly to the anal opening. The circulatory system consists of a dorsal tube running close to the dorsal wall, and two lateral divisions which unite anteriorly and posteriorly and also are connected by transverse branches. The blood is colorless and in some cases provided with nucleated corpuscles which may contain hæmaglobin. The nephridial system is represented by two ciliated canals more or less coiled and with external openings in the anterior part of the body. Internally they terminate in flame cells. The reproductive organs are very simple and are located in separate individuals, though a few species are hermaphroditic. The ovaries are simple sacs arranged serially on each side and opening externally by means of small pores, the ova being extruded in gelatinous tubes. Fertilization in some forms at least is internal, but observations on methods of fertilization are scant. The Nemerteans seem to present some points of resem-

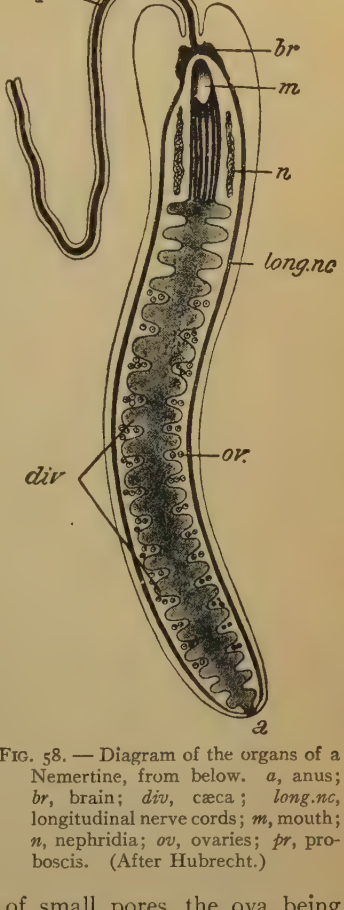


FIG. 58. — Diagram of the organs of a Nemertine, from below. *a*, anus; *br*, brain; *div*, cæca; *long.nc*, longitudinal nerve cords; *m*, mouth; *n*, nephridia; *ov*, ovaries; *pr*, proboscis. (After Hubrecht.)

blance to the Turbellarians and show some decided points of advancement, especially in the alimentary tract, circulation, and development of the proboscis. While they have been thought by some to show development toward the vertebrates, they certainly stop very far short of that goal and may better be looked upon as

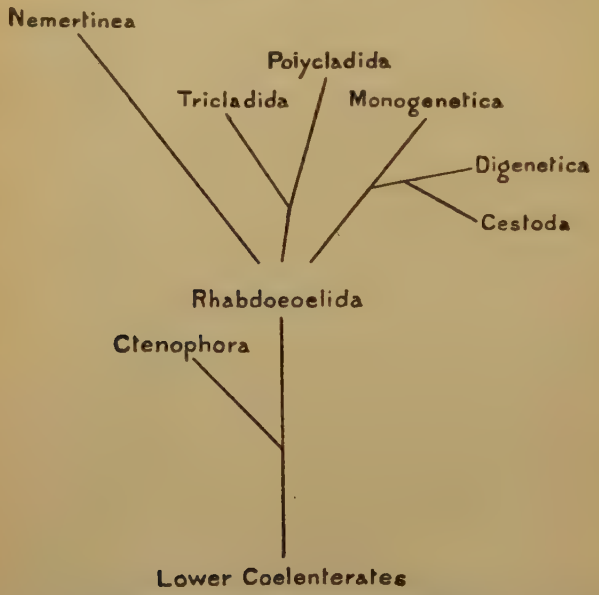


FIG. 59. — Diagram of the relationships of the platyhelminthes (together with the nemertinea). (After Parker and Haswell.)

an offshoot which has retained most of the primitive characters of the earlier groups.

Most of the species live in mud or under stones and among aquatic vegetation, some of them swimming about freely, while a few are found within the mantle cavity of marine bivalves, and some again within the bodies of tunicates, feeding upon material gathered by the host. The proboscis, which is thrust out violently on certain occasions, is sometimes separated from the body,

and has even been thought by some of the earlier observers to be a separate animal. Its function seems somewhat uncertain, although that it is a tactile organ seems very probable, and it may also serve as a defensive organ, since it is armed with minute spines or stylets.

There is practically no economic or commercial importance connected with these forms, and they do not occur in such an abundance as to form an important factor in marine life. They may, of course, have some importance in relation to other marine forms, since they feed on a considerable variety of other animals, and they may also serve as food materials for other animals.

CHAPTER V

ROUND WORMS

Class Nematoda

The Nematodes are slender, unsegmented, thread-like animals, living of necessity in moist regions, many of them parasitic in higher animals, others living in plants, moist earth, or water. The body surface is provided with a thick cuticle, the alimentary tract is continuous through the body, the mouth opens at the apex anteriorly, and the anal opening is located usually near the

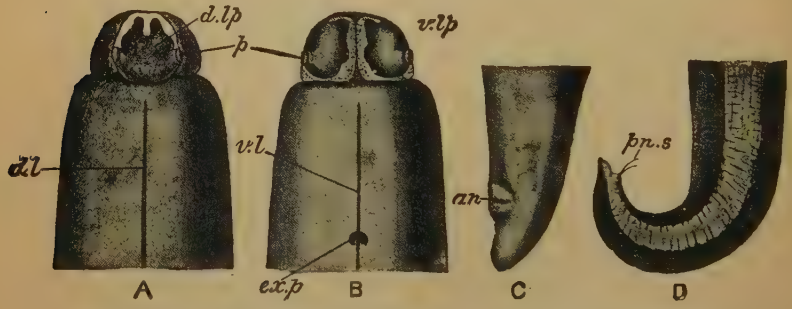


Fig. 60. — **Ascaris lumbricoides.** A, anterior end from above; B, the same from below; C, posterior end of female; D, of male, side view. *an*, anus; *d.lp*, dorsal lip; *d.l*, dorsal line; *ex.p*, excretory pore; *p*, papillæ; *pn.s*, penial setæ; *v.l*, ventral line; *v.lp*, ventral lip. (After Leuckart.)

posterior end. There are no special organs for circulation or respiration, but the excretory system consists of two tubular organs with one external opening. The sexes are generally distinct and the development usually direct, although the life cycle is often complicated in adapting them to particular host relations. One of the best known species is the large round worm of the

horse, *Ascaris megalocephala*, which occurs in the alimentary canal. The female is nearly as thick as a lead pencil, varying from eight to sixteen inches in length, while the male varies from three to seven inches in length. The thick chitinous cuticle is continuous except at the openings at the mouth, excretory pore, and anal and reproductory openings. The digestive system consists of a long alimentary tract, the mouth opening at the tip of the head end, the esophagus expanding at some distance from the mouth into a bulb provided with chitinous teeth. This opens into the stomach, or mid-gut, and this into the intestine, which extends back to the short rectum or proctodeum. A slender nerve ring surrounds the pharynx, and from this six delicate nerves run forward and six backward. The ganglion cells are scattered in the ring, there being no definite ganglionic enlargement. Sensory organs occur in papillæ surrounding the mouth, and in the male in the tail region also. The ovaries consist of two tubes which pass into the oviducts, and these are continued into rather long uteri, which may become gorged

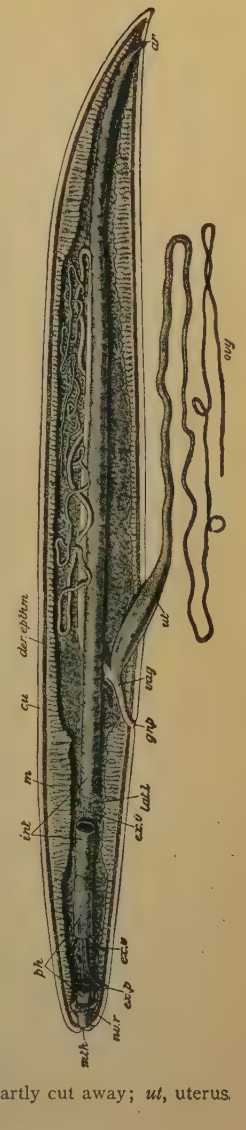


FIG. 61. — **Ascaris lumbricoides.** Semi-diagrammatic dissection of the female. *an*, anus; *cu*, cuticle; *der.epthm*, deric epithelium; *ex.p*, excretory pore; *ex.v*, excretory vessel; *gnp*, gonopore; *int*, intestine partly cut away; *lat.l*, lateral line; *m*, muscular layer; *mth*, mouth; *nv.r*, nerve ring; *ovy*, ovary, that of the right side in situ, the left spread out; *ph*, pharynx, partly cut away; *ut*, uterus. (From Parker and Haswell.)

with eggs, and which unite into a short vagina. The genital openings are on the ventral line anteriorly. The testis is single, consists of a coiled tube which merges into the vas deferens, leading to the seminal vesicle and ejaculatory duct, ending in a genital aperture near the anus. Fertilization of the eggs occurs in the oviduct, and the eggs are discharged into the alimentary canal of the host and distributed with the fæces over vegetation, from which probably the reinfection of the host or other animals occurs.

Aside from the importance of this species as a parasite it has been much studied because of the interest attached to the karyokinesis, since it represents a quite simple form of chromosome arrangement.

A nearly related species (*Ascaris lumbricoides*) occurs in man and also in the sheep and hog. Doubtless the digestive processes or the conditions of the alimentary tract in these different hosts are about equally favorable for its development. Opportunity for infection, however, must be much more favorable for the lower animals, as both in the drinking water and herbage upon which they feed they meet the most favorable conditions for infection. The worm is a long, rather thick species, the female measuring from eight to ten inches in length and one fifth of an inch in diameter, males six to seven inches in length and about one eighth of an inch in diameter. The female is conical at the posterior end; the genital opening is in the forward third of the body and located in a rounded depression. In the male the hinder end is curved downward and bears two short spicules and a large number of papillæ. The eggs are discharged into the alimentary tract of the host, from which they are expelled, and their further development requires both warmth and moisture. The embryo completes its development in from four to six weeks when it rests within the egg shell, and after this stage it appears necessary for it to secure entrance to another host. It was believed by Leuckart that an intermediate host was necessary and that from this intermediate host they must find their way to the

adult host; that is, man, sheep, or hog. But other observers believe that no second host is essential, but that the eggs, including the embryos ready for hatching, may be swallowed by the final host either in food or water and that the development of the embryo then proceeds directly to the adult stage.

The amount of disturbance caused by the species depends not only on the number of parasites present, but also on the susceptibility or irritability of the host individual. In some instances immense numbers of the worm have been found in a single individual, as high as five hundred to one thousand being recorded, and the symptoms produced by such infection are severe nervous irritability, hysteria, and in some cases convulsions. In some cases, penetration of the ducts leading into the alimentary tract gives rise to other disturbances, but ordinarily the worm seems to remain quite constantly in the alimentary tract.

The treatment of this parasite rests in the use of strong vermifuges, a considerable list of these being in general use.

Another common species, and one that causes great fatality among dogs, especially puppies, is *Ascaris mystax*. It is, perhaps, one of the greatest sources of loss to breeders of fancy dogs. Infection of puppies occurs easily if adults are infested, as eggs may be scattered in the litter of kennels.

The Stomach Worm of Sheep (*Hæmonchus contortus*). This is one of the most frequent parasites of sheep, and perhaps causes greater loss than any other species of sheep worm. It abounds in the fourth stomach of sheep and goats. It is a very small, thread-like species, the male being less than one inch in length, and the female about an inch or a little more. It is so slender that it may very easily escape notice unless searched for with particular care. They are sometimes reddish in color and at other times of a dirty white color, being affected by the quantity contained in the alimentary tract. The development is thought to be direct and the disease readily communicated to healthy sheep in the same flock. The adult worms are present in the stomach at all seasons of the year, and eggs discharged from their

bodies are carried to the surface of the earth in the fæces. Eggs hatch, larvæ crawl up grass blades, and thus readily gain entrance to the stomachs of other individuals. Most authors have ascribed the work of infection to stagnant water, where the embryos have been observed to develop, but recent studies show that young worms crawl up grass blades and become inactive waiting entrance into a host. Lambs appear to suffer more than adult sheep, and they may die off in considerable numbers, sometimes before any serious trouble has been noticed, but more often after a period in which they appear to droop and become emaciated.

The loss from this species may be prevented in a large degree by particular attention in starting a flock to secure uninfected animals, the same precaution being observed in the introduction of new animals. Frequent change in pasturage and careful attention to the water supply are necessary. Dr. Curtice recommends as a direct treatment the use of an emulsion of oil of turpentine and milk, one part turpentine to sixteen of milk. The mixture is well shaken to emulsify the turpentine, and each animal given from two to four ounces of the mixture according to age. Other vermifuges may be used, but this preparation is as available as any that can be recommended for general use.

The Nodular Worm of the Sheep (*Œsophagostoma columbianum*). —This injurious parasite of sheep was described in 1890, and from occurrences in the Eastern States; since that time it has been found to exist over a great portion of the country, and probably the reason for its escaping notice was that the disease could be readily mistaken for other troubles. The distinctive character of the disease is the occurrence of numerous small nodules in the walls of the large intestine, especially of the upper portion, and it has been frequently mistaken for intestinal tuberculosis. So close is this resemblance that the government inspectors at the various slaughter houses have on some occasions in the past mistaken it for that disease. Each of the nodules incloses a small thread-like worm about one eighth of an inch long. The head is bent into the form of a hook, and there are six papillæ

at the head end, two above, two beneath, and one on each side of the mouth opening.

Trichina. — The common trichina (*Trichinella spiralis*) is probably better known and preventive measures against it more commonly used than for any other parasitic form. Doubtless the great majority of American people are familiar with the danger of eating uncooked pork on account of the possible presence of this parasite and the usually fatal character of the infection from it. Moreover, the international complications that followed the exclusion of American pork from German markets, stated to be for the reason of infection from trichina, the establishment of a national inspection system, and the general inspection methods which followed, have brought it to the attention of the people in general.

Trichina occurs in the flesh of the hog or other host animal, imbedded in the muscle fibers and inclosed within a cyst which, at first soft, becomes gradually filled with a limy deposit which forms a hard incasing wall. The cysts may number as high as 100,000 to 125,000 to the cubic inch of meat, and it is easy to understand that eating such an amount of living trichinæ, the liberation of these in the alimentary canal, and the subsequent development from them of, perhaps, 600 to 1500 individuals from each female, would produce such an enormous number of young trichinæ as to result in very serious symptoms. When taken into the stomach the cysts are dissolved, the trichinæ set free, after which they mature quickly, there being usually about equal numbers of males and females. These differ considerably in size. After mating, each female produces viviparously a large number of young, which proceed to burrow through the walls of the stomach or intestine and migrate through the surrounding tissues. Many are doubtless carried in the blood vessels, so that they reach distant parts of the body in a short period, but the greater proportion appear to locate in the diaphragm or the muscles of the shoulder or ham. Here they attain a certain amount of growth, imbedding themselves in the muscle fibers, becoming incased in

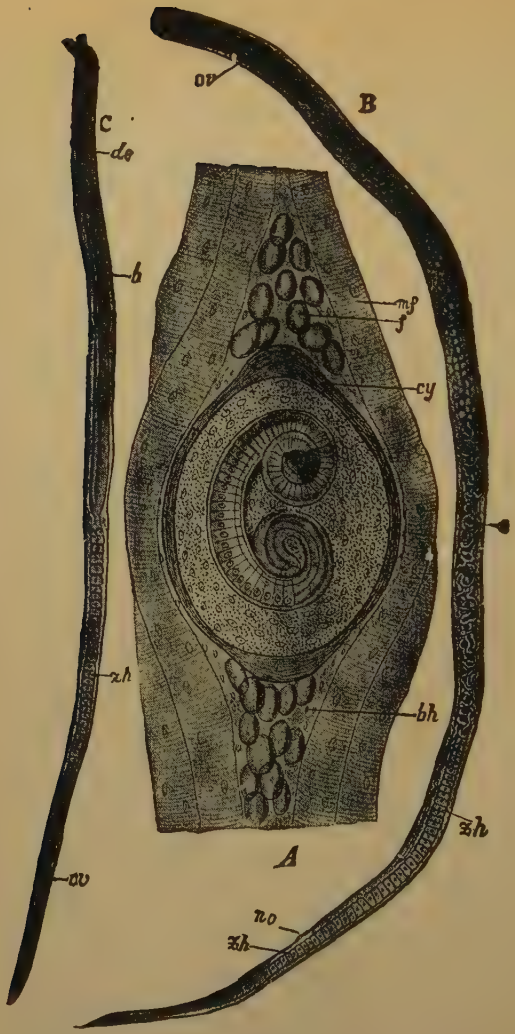


FIG. 62. — **Trichina spiralis.** A, encysted form in muscle of host; B, female; C, male. *bh*, connective tissue envelope; *cy*, cyst; *de*, ejaculatory duct; *e*, embryos; *f*, fat globules; *h*, testis; *mf*, muscle fiber; *æ*, pharynx; *ov*, ovary; *wo*, gonopore; *zh*, cell masses in intestine. (From Lang's *Comparative Anatomy*, after Claus.)

the cyst and then remain inactive for an indefinite period. The migration, however, causes much irritation to the muscles, and the symptoms are cramping pains, rheumatic symptoms, etc., being due to the muscle irritation. Local symptoms depend, of course, upon the particular muscles invaded. In the heart or walls of the arteries circulation is interfered with, in the diaphragm or intercostal muscles, respiration is affected, and invasion of the facial muscles of vision or speech will affect these particular functions. If the host survives the migration until the trichinæ come to rest and the muscle fibers become adapted to their presence, these symptoms may subside and recovery ensue.

If the flesh of any animal containing trichina in this encysted condition be eaten by any susceptible animal, this same cycle results. Thus it is seen that each host animal serves as host for the same cycle of growth, and there is no such necessary alternation between two particular host forms as in the case of the tapeworm. That is, hogs may become infested by eating scraps of pork or by eating dead rats or the flesh of any animal infected, and in like manner, while the human species ordinarily becomes infested from the hog, infection might just as readily come from eating rats and cats if these were common articles of diet and were eaten in the uncooked form. The common practice of thoroughly cooking meat for the prevention of this infection furnishes a sure safeguard. The practice of curing hams, now so general, affords some protection, but the safest rule to follow is to thoroughly cook all kinds of pork. The inspection of animals when slaughtered under methods that are practicable on a large scale is not a guarantee against trichina, and is considered of so little value that government inspection as now applied does not include trichina. Therefore all pork, whether having been inspected or not, should be thoroughly cooked before being eaten.

Gordiacea. — The hair worms are extremely slender, thread-like worms that are found as parasites in various insects or crustaceans, and which often awaken much interest or even alarm by their appearance in water troughs, in cabbages, or other unusual

places, while the old superstitious belief that they were derived from horsehairs that had been submerged in water and had taken on this form of life is without the slightest foundation and appears absurd to any one who is at all familiar with the laws of life. It still persists in some quarters, as do occasional panics as to the danger from their occurrence in cabbages or other vegetables.

One of our common American species, *Mermis albicans*, is a frequent parasite of grasshoppers, and in so far as it reduces the numbers of these pests may be counted a beneficial species. It is fifteen to eighteen inches long, but so slender as to appear like a thread, and I have seen five, with a total length of over five feet, in a single grasshopper which, though doubtless much inconvenienced, and incapable of reproduction, was still alive and active. This species is doubtless the basis for most of the alarm that has at times spread over the country concerning "cabbage snakes," and which has in some years in certain localities caused the loss of hundreds of thousands of dollars on the cabbage crop simply from the unfounded fear that cabbages might be infested with them and prove poisonous. Their occurrence in cabbages or other plants is easily accounted for from their habit of leaving the host when they have matured, so that they might occur wherever the grasshopper may have been resting. They pass into the ground, however, to end their career, laying eggs in autumn, which hatch in the following summer into minute worms that find their way into the bodies of grasshoppers, where they live and grow during the summer and early fall.

Class Acanthocephala — Thorn-headed Worms

These are extremely specialized parasitic forms that differ from the Nematodes in the reduction of the alimentary tract and the development of a special organ for attachment, a conspicuous process from the head end that is covered with minute spines directed backward and serving to anchor the animal firmly to its

host. They live in the alimentary canal of various hosts among the warm-blooded animals and fishes, the most common and best-known species being one that infests hogs. This species, the *Echinorhynchus gigas*, is several inches long, and the protruding spiny anchor is imbedded firmly in the wall of the intestine of the host. There is no mouth or digestive organs, but food is absorbed through the body walls. The nervous system is reduced to a small ganglion in the anterior end, and organs of circulation and respiration appear to be entirely wanting. The reproductive organs are large, the ovaries occupying the larger space of the body, and the oviducts opening at the end of the body.

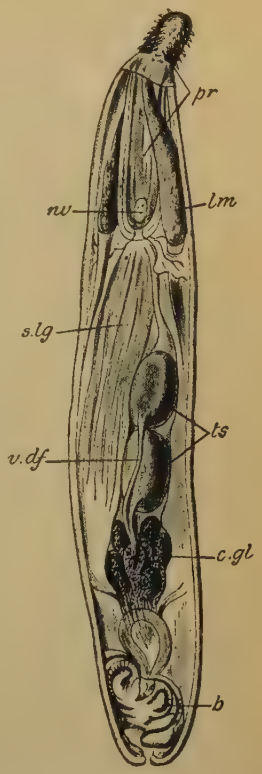


FIG. 63. — **Echinorhynchus gigas**. Dissection of male. *b*, bursa; *c.gl*, cement glands; *lm*, lemnisci; *nv*, nerve ganglion; *pr*, proboscis; *s.lg*, suspensory ligament; *ts*, testis; *v.df*, vas deferens. (After Leuckart.)

The life history involves two hosts, and in this species the intermediate host is, in Europe, the common cockchafer, *Melolontha vulgaris*, while in America it has been shown by Stiles that the larvæ develop in the common white grub, *Lachnosterna fusca*. This life history being known, it is an easy matter to prevent the infection of hogs by taking pains not to pasture them on land that has been recently occupied by infested hogs, without shutting them out entirely from rooting in land that is infested by the grub. A lapse of three years will insure the maturing of all grubs that may have been in any field, and hence this interval between times when hogs are allowed to feed upon grubs

in any field will avoid infection even if hogs have been infested.

Other species occur in other animals, one, the *Echinorhynchus proteus*, occurring as adult in the pike and having as its intermediate host an aquatic crustacean, *Gammarus pulex*, while another, *Echinorhynchus angustatus*, infesting the perch, passes its intermediate stage in an *Isopod*, *Asellus aquaticus*.

CHAPTER VI

ANNELIDA

The Annelids present us with a very considerable advance in structure from the preceding groups, the body being composed of a series of connected segments and having a well-developed nervous system, circulatory system, and nephridia. Familiar examples are found in the earthworm and in certain marine species. The group is separated into two principal classes, the Chætopoda and the Hirudinea, or Leeches, these differing mainly in that the first have setæ and the latter strong suckers.

Class Chætopoda

In this class the sides of the body are provided with bristle-like structures or with parapodia, locomotory structures which are distributed usually throughout the length of the body and appear on each segment. The alimentary tract extends through the body, opening at the first segment in a simple mouth and at the terminal segment in the anal opening. The nervous system consists of a double chain of ganglia giving off lateral nerves to the segments. The segmental organs, or nephridia, occur in most of the segments from near the head to near the posterior end. The circulatory system is complex, consisting of a dorsal vessel connecting anteriorly with the ventral vessels, the flow of the blood being forward dorsally and backward in the ventral vessels. The characters of the group may be well understood from the study of the earthworm, which is a form commonly used as the type of the class.

The earthworms are a very common form of life over all parts of the earth and in general appearance they all look very much

alike. One may notice differences in size and color at least at different seasons of the year, and a more careful study will reveal the fact that there are a number of quite different kinds, the species being separated by differences in the number of segments,

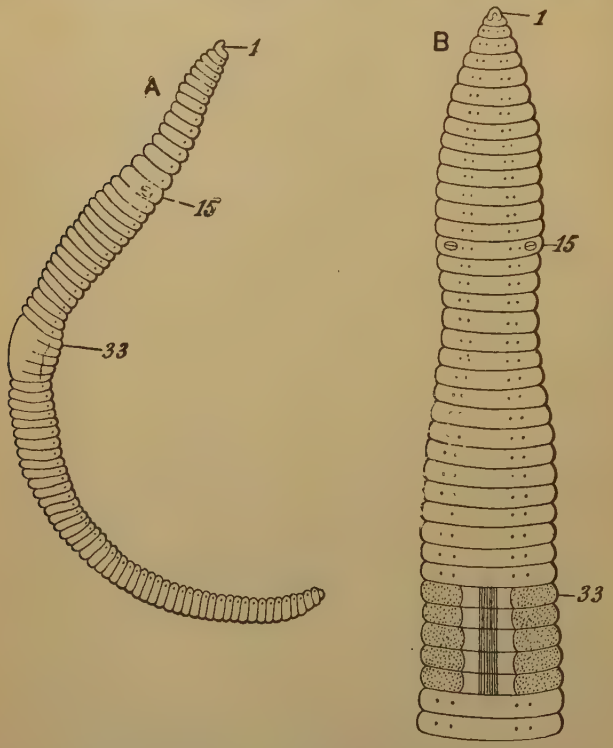


FIG. 64. — **Lumbricus agricola.** A, entire specimen, lateral view; B, ventral view of anterior part of body, magnified. *1*, *15*, *33*, first, fifteenth, and thirty-third segments. Black dots represent setæ. (From Parker and Haswell.)

position of clitellum, number of dorsal pores, and other characters which need not be mentioned here. So far as a general dissection goes it matters but little which one of these species is taken, although the larger forms are more easy to handle.

Earthworms may be found by turning over boards in damp places, taking a spade and digging a few inches into the soil where the earth is fairly rich and damp, by following closely behind a plow and watching for the worms turned out in the furrow, or, in some cases, after rains they may be found in large numbers on the surface of the ground. During the day they are ordinarily concealed in the ground, but issue at night and feed upon vegetation, burrowing again into the soil before bright daylight.

They are elongate and nearly cylindrical, capable of considerable extension and contraction. The body consists of a large num-

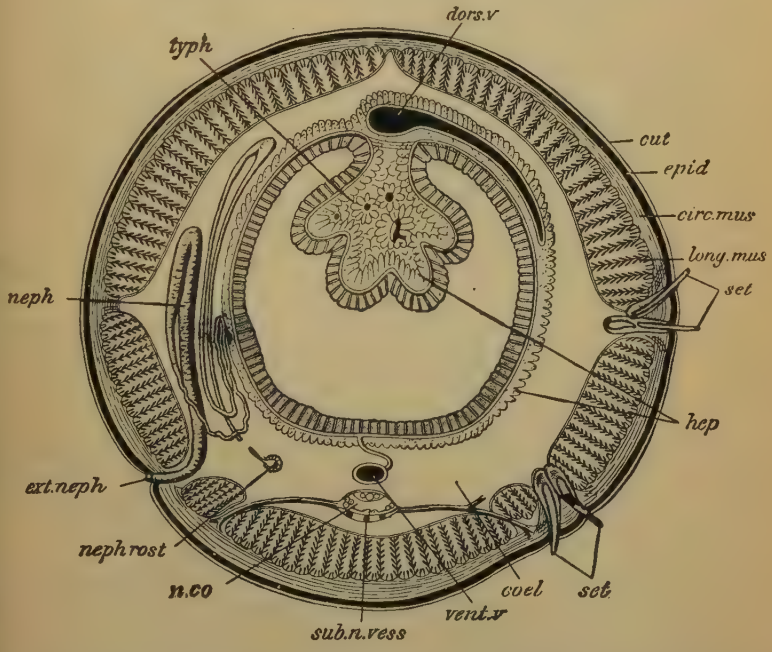


FIG. 65. — **Lumbricus**. Transverse section of the middle region of the body. *circ.mus*, layer of circular muscular fibers; *cœl*, cœlome; *cut*, cuticle; *dors. v*, dorsal vessel; *epid*, epidermis; *ext.neph*, nephridiopore; *hep*, layer of chloragin cells; *long.mus*, longitudinal muscle; *neph*, nephridium; *nephrast*, nephrastome; *n.co*, nerve cord; *set*, setæ; *sub.n.vess*, subneural vessel; *typh*, typhlosole; *vent.v*, ventral vessel. (After Marshall and Hurst.)

ber of segments, most of these being similar to each other. The first segment bears a prominent protrusion or **prostomium**, the under portion of which is excavated and forms the upper margin of the mouth opening. In mature specimens segments about thirty to thirty-five are somewhat swollen and form a girdle, the **clitellum**, which is used in copulation. The other segments, though apparently similar and without distinct structure, have in reality considerable difference. They bear four pairs of minute bristle-like structures, the locomotor **setæ** which can be seen by careful examination, and slightly below these all the segments except the anterior four and posterior one have openings for the excretory organs. Along the dorsal line, the dorsal part of the segments have minute pores opening into the body cavity. These, however, are too minute to be seen without special preparation. The mouth opening at the head end of the body and the anal opening posteriorly connect with the alimentary tract. The other external openings consist of an outlet for the oviducts on segment fourteen, the sperm duct on segment fifteen, and the sperm receptacles on segments nine and ten. Internally, the alimentary canal is the most conspicuous structure, extending the entire length of the body from the mouth in the anterior segment to the anal opening in the posterior segment. From the mouth opening the buccal cavity passes into a muscular pharynx, which is followed by a rather short esophagus, the crop occupying segments ten to fifteen, this passing into an elongated stomach and intestine which are slightly differentiated and which have along the dorsal line a broad **typhlosole**, which is richly supplied with **chlorogogue** cells, the function of which is supposed to be similar to that of the liver cells in other groups, and possibly excretory and phagocytic also. The circulatory system is somewhat complex, and includes a dorsal vessel running nearly the length of the body, but branching anteriorly and forming five lateral vessels which pass around the alimentary tract and merge below into a ventral vessel lying below the alimentary canal and in which the blood has a backward flow. There are also several delicate ves-

sels lying below the nervous cord. Respiration is provided for in the absorption of air through the body walls. There are paired excretory organs, the segmental organs, or **nephridia**, which consist of an internal ciliated funnel connecting with a tubular duct, which is the functional part of the organ, and a muscular sac, or reservoir, in which waste matter is temporarily held and from which it is ejected to the surface through external apertures that open beneath the locomotor setæ. These segmental organs occur in all the segments from near the head of the body to the next to the last. These structures are of considerable interest as homologues of excretory organs appearing in other

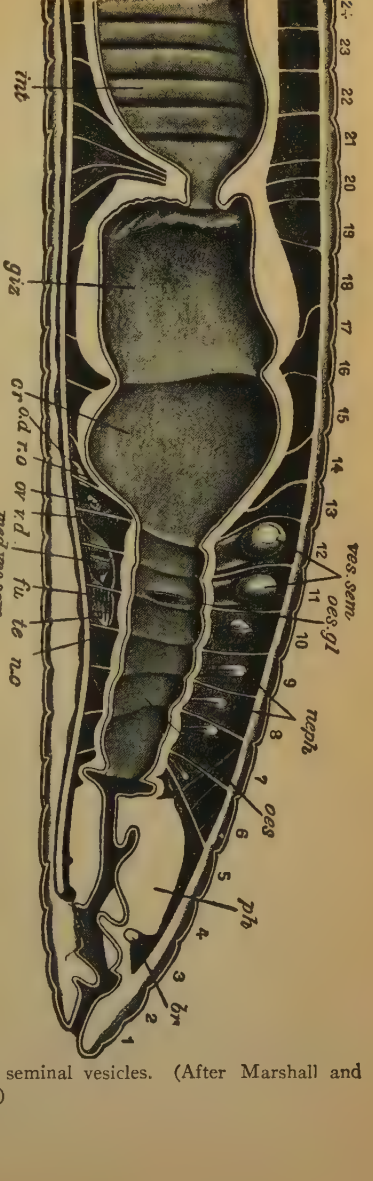


FIG. 66. — **Lumbricus herculeus.** Longitudinal vertical section through the anterior part of the animal; *br*, brain; *cr*, crop; *fu*, seminal funnel; *int*, intestine; *med.ves.sem*, middle seminal vesicle; *n.c*, nerve cord; *neph*, nephridia; *o.d*, oviduct; *œs*, esophagus; *œs. gl*, esophageal glands; *ov.*, ovary; *ph*, pharynx; *r.o*, receptaculum ovarum; *te*, anterior testes; *ves.sem*, posterior lateral seminal vesicles. (After Marshall and Hurst, from Parker and Haswell.)

groups of animals, and may be considered as of rather primitive form in that they are separate and each one provided with its external opening.

The muscles are arranged as circular and longitudinal fibers, the latter within the former as shown in the cross-section, and locomotion is accomplished by alternate contractions and relaxations, contraction of the circular muscles extending the worm and of the longitudinal muscles drawing the ends closer. Muscles of the locomotor setæ serve to fix these in position and permit of forward or backward movement.

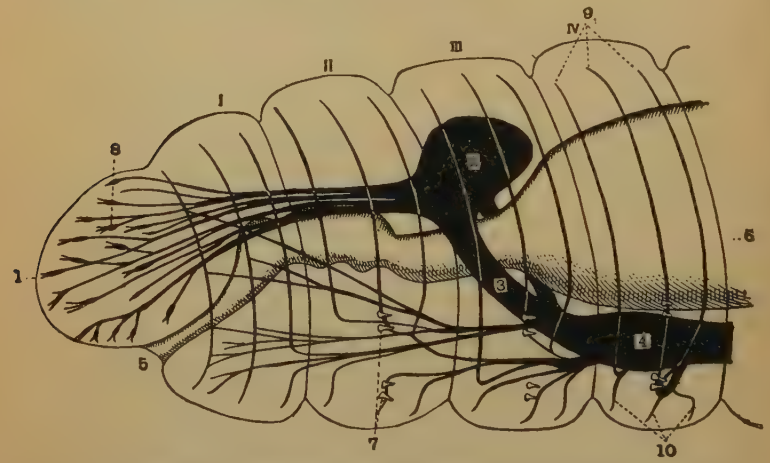


FIG. 67. — Diagram of the anterior end of **Lumbricus herculeus** to show the arrangement of the nervous system. I, II, III, IV, first, second, third, and fourth segments. *1*, prostomium; *2*, cerebral ganglia; *3*, circumoral commissure; *4*, 1st ventral ganglion; *5*, mouth; *6*, pharynx; *7*, dorsal and ventral pair of setæ; *8*, tactile nerves to prostomium; *9*, anterior, middle, and posterior dorsal nerves; *10*, anterior, middle, and posterior ventral nerves. (After Hesse, from Shipley and McBride.)

The nervous system is located just above the ventral wall, and consists of a pair of ganglia in each segment, these being closely approximated and connected by fibers, so that there is a continuous chain from the head to the posterior end.

In the head region the structure is modified, the nerve cords

separating and passing around the esophagus. The ganglia above the esophagus are somewhat larger than those of the other segments and give off a number of nerve fibers which pass to the body surface and serve doubtless for the transmission of sensory impulses.

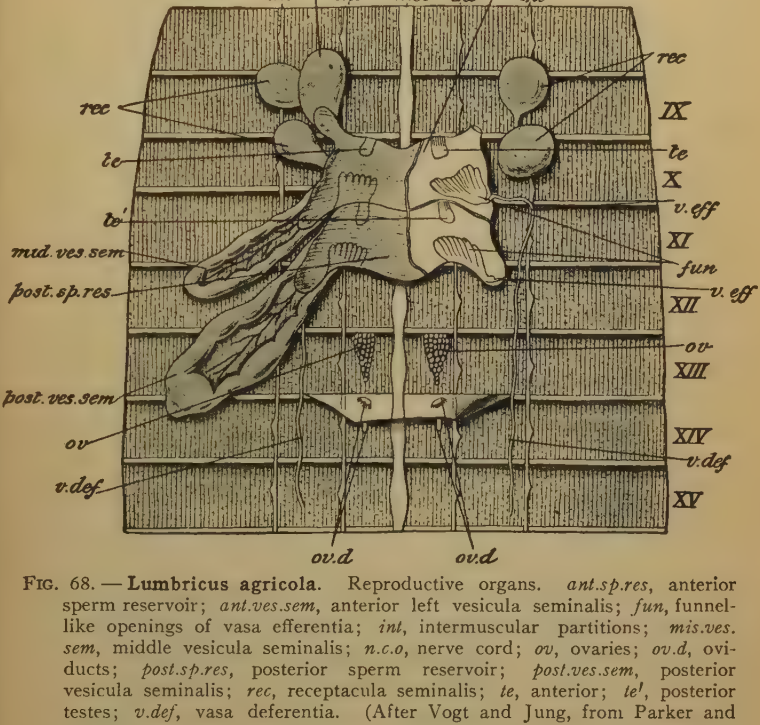


FIG. 68. — **Lumbricus agricola.** Reproductive organs. *ant.sp.res*, anterior sperm reservoir; *ant.ves.sem*, anterior left vesicula seminalis; *fun*, funnel-like openings of vasa efferentia; *int*, intermuscular partitions; *mis.ves. sem*, middle vesicula seminalis; *n.c.o*, nerve cord; *ov*, ovaries; *ov.d*, oviducts; *post.sp.res*, posterior sperm reservoir; *post.ves.sem*, posterior vesicula seminalis; *rec*, receptacula seminalis; *te*, anterior; *te'*, posterior testes; *v.def*, vasa deferentia. (After Vogt and Jung, from Parker and Haswell.)

The special senses in the earthworm are not highly developed, but it reacts promptly to contact, so that there is evidently a well-developed tactile sense. Taste and smell are doubtless present though not greatly specialized, and hearing is present, if at all, simply as the recognition of vibrations through the body surface.

There are no special organs for vision, but since the worm reacts promptly to light, the nerve endings of the anterior end of the body have, no doubt, an ability to distinguish light from darkness.

The reproductive organs are rather complex and both sexes are found in each individual. The ovaries are rather small bodies lying in the thirteenth segment, and the ova discharged from these are carried to the outside through small oviducts, the internal opening of which is in the thirteenth segment, while the external aperture is on the ventral side of the fourteenth segment. The testes are located in segments nine and ten, and are associated with large sperm vesicles and from which the spermatozoa are carried through long cylindrical **vasa deferentia** which open separately in two minute apertures on the fifteenth segment. The sperm or seminal receptacles lie in the ninth and tenth segments, and during copulation, when two worms mutually fertilize each other, they are held together by the clitellum, the head ends in opposite directions, so that the sperm receptacles of one individual oppose the openings of the vas deferens in the other. The ova are formed into small packets and held within the gelatinous sheath formed by the clitellum, and this, when the ova have been received, is drawn forward over the body, and presumably the spermatozoa in the sperm receptacles are forced into the capsule with the egg mass, so that fertilization is accomplished by means of spermatozoa from the other individual, at the time that the clitellum is slipped off from the body. The ova remain inclosed in this capsule-like envelope and in this form remain in the earth and undergo a development through the earlier embryonic stages, reaching the form of the adult worm before hatching. In this the earthworm presents a striking contrast to such aquatic annelids as hatch from the egg in a quite primitive form and swim about as larvæ, later taking on the shape and characteristics of the adult. This indicates that the earthworm has been modified by its subterranean habit, and in character of its development should be considered rather more specialized than the aquatic forms. Egg capsules are formed in spring or early summer,

and the young worms grow mainly during the summer months. Sometimes large clusters matted together may be found in autumn packed away under clods or in banks where there is a favorable condition of moisture.

The earthworm presents some very interesting relations to the human species, affecting human interests in somewhat different ways. On account of their immense numbers and the fact that they burrow constantly through the soil, carrying organic matter into deep burrows and bringing portions of the subsoil to the surface, where they eject it in the form of castings, they serve to render the soil more fertile. The extent of this transfer has been determined in the classic experiments by Darwin to reach about three inches in the course of twenty years. Aside from the interchange of the soil there is an additional fact, that in their burrows they loosen up hard portions of the earth and permit more ready entrance of roots and better movement of soil moisture, so that they are considered as distinctly helpful in increasing the fertility of the soil. On the other hand, they feed upon vegetation above ground, sometimes dragging portions of leaves into their burrows, and, if these attacks are made upon plants which are valuable crops, the loss may be of importance.

Earthworms constitute a most important factor in the food supply of many different animals. Birds feed upon them in great numbers, the robin especially having become very expert in locating them in their burrows, from whence they drag them forth to serve as food for themselves or their young nestlings. Moles and other subterranean forms feed largely upon them, and as they are often washed into streams, they become available as fish food. Fishes certainly appreciate them, as they constitute one of the most seductive forms of bait, and if we consider for a moment how universally this humble creature is used in this way, we can recognize how important a factor it has been in providing food for the human species. Earthworms of different kinds occur in various parts of the world, and some reach an enormous size compared with those which are common here. One of the species in South

Africa is said to reach a length of several feet and the thickness of a man's thumb.

Related to the earthworms are a number of fresh-water forms which possess slender setæ and very slender bodies, most of them occurring in mud at the bottom of pools or streams, some of them swimming about freely, and all of them rather minute in size. The family *Naididæ* includes

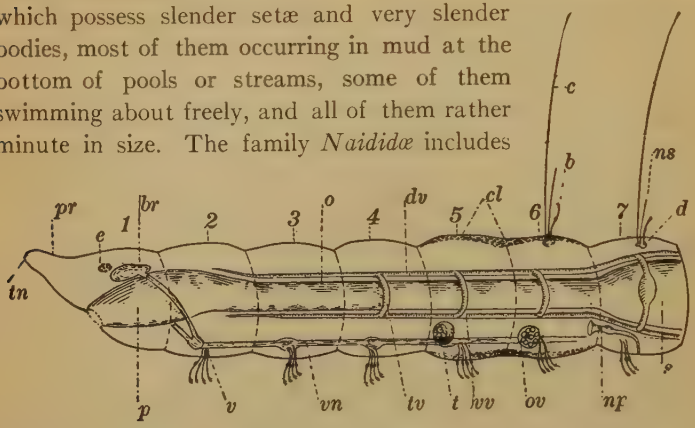


FIG. 69. — Diagram of **Naid** illustrating characters used for separating genera and species. *b*, biuncinate seta; *br*, brain; *c*, capilliform seta; *cl*, clitellum; *d*, dorsal bundle of setæ; *dt*, distal tooth, biuncinate seta; *dv*, dorsal blood vessel; *e*, eye; *n*, nodulus; *np*, nephridium; *ns*, needle-like seta; *o*, esophagus; *ov*, ovary; *p*, pharynx; *pr*, prostomium; *s*, stomach; *t*, testis; *tn*, tentacular process; *tv*, transverse blood vessel; *v*, ventral bundle of setæ; *vn*, ventral nervous system; *vv*, ventral blood vessel; *1–7*, seven anterior segments. (After Walton.)

a considerable number of these fresh-water species which from their abundance must constitute a somewhat important factor in aquatic life. Our species are mostly small, requiring the microscope for study, and usually are found in the débris at the bottoms of pools, streams, or other bodies of water, where they feed upon aquatic vegetation. They reproduce commonly by budding or division, and the structure may best be shown by the accompanying figures.

The common Dero constructs a protective case somewhat after the fashion of those of the caddice flies, and then this case, which it drags around with it as it moves, protects it well from enemies that seek it as a food.

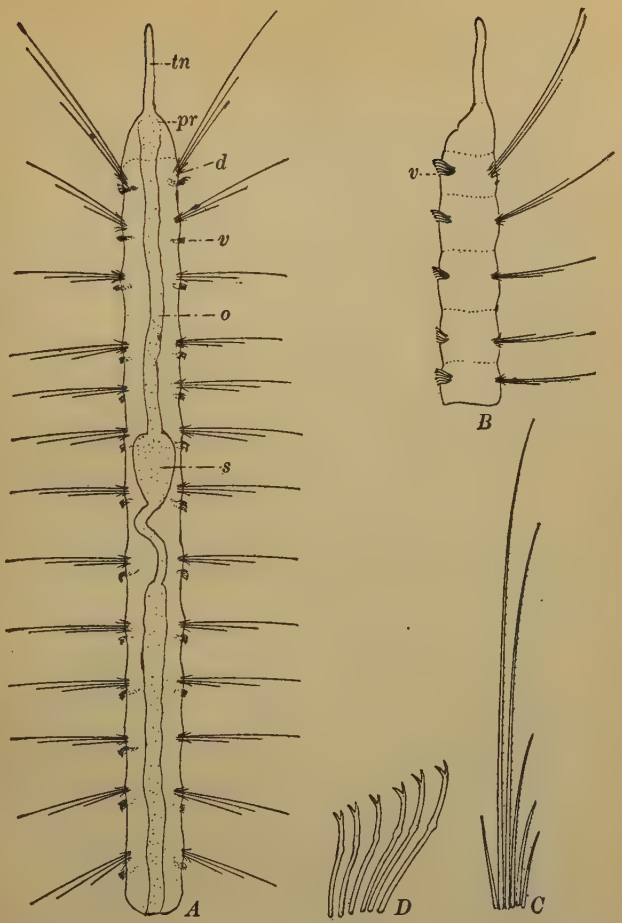
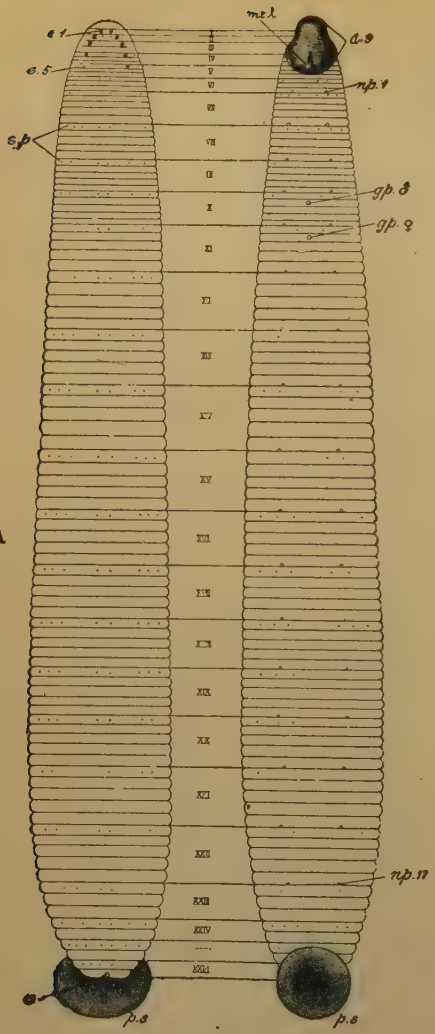


FIG. 70. — **Pristina serpentina**. A, dorsal aspect (× 50). B, lateral aspect, first six segments (× 50); C, dorsal bundle of setæ of seventh segment (× 250); D, ventral bundle of setæ (× 250). (After Walton.)

The preceding forms with others having simple setæ form the group *Oligochæta*, while the forms with broad **parapodia** form a group, *Polychæta*, most of the members of which are marine. Of



A B

Fig. 71. — **Hirudo medicinalis.** A, dorsal; B, ventral aspect; *a*, anus; *a.s*, anterior sucker; *e. 1*, first pair of eyes; *e. 5*, fifth pair; *gp.* ♂, male gonopore; *gp.* ♀, female gonopore; *mth*, mouth; *np. 1*, first pair of nephridiopores; *np. 17*, seventeenth pair; *p.s*, posterior sucker; *s.p*, sensory papillæ; I–XXVI, segments. (Partly after Whitman, from Parker and Haswell.)

these the species of Nereis are conspicuous and numerous, and doubtless constitute a considerable element in the food of marine fishes. Moreover, they are used to some extent as bait in some of the salt-water fisheries.

Class Hirudinea

This group, including the leeches, is usually distinguished from the previous class by the flattened form, the absence of locomotory setæ, and the presence of large muscular suckers at the head and tail ends. The

common leech is perhaps as convenient an example as any, and this is from two to four inches long and capable of extending itself to a length of five or six inches, and when closely contracted may be not more than one and a half to two inches in length. It is commonly attached by a large posterior sucker, and in moving, the head end is thrust forward, often waving from side to side to select a suitable point to attach itself, and when this is found, the hind sucker is released and by a sudden movement brought close to the anterior sucker and very quickly attached, the anterior sucker again being loosened. In this manner it may progress with considerable rapidity, and at times it may release both suckers and swim freely in the water. The body surface is transversely striated, so that it has the appearance of possessing an immense number of segments.

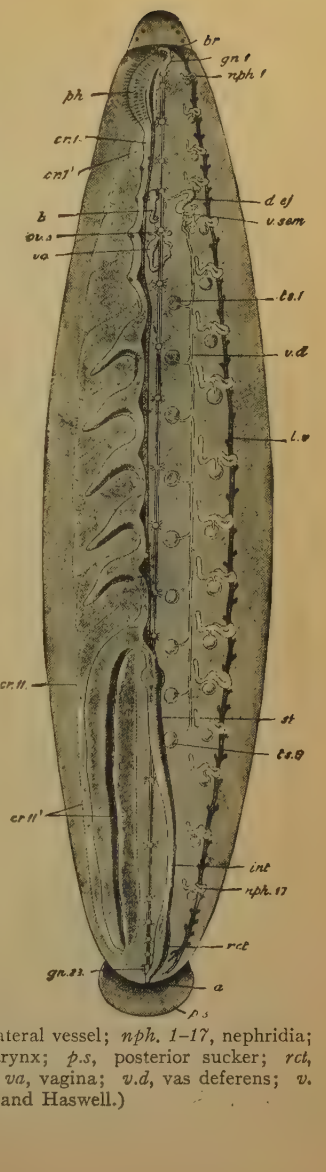


FIG. 72. — **Hirudo quinquestriata.** Dissection from the dorsal aspect. *a*, anus; *br*, brain; *cr. 1*, first diverticulum of crop, contracted; *cr. 1'*, the same expanded; *cr. 11*, the last diverticulum of the crop, contracted; *cr. 11'*, the same expanded; *d.ej*, ductus ejaculatorius; *gn. 1–23*, ganglia of ventral nerve cord; *int*, intestine; *l.v*, lateral vessel; *nph. 1–17*, nephridia; *ov.s*, ovarian sac; *p*, penis; *ph*, pharynx; *p.s*, posterior sucker; *rct*, rectum; *st*, stomach; *ts. 1–9*, testes; *va*, vagina; *v.d*, vas deferens; *v. sem*, vesicula seminalis. (After Parker and Haswell.)

This, however, does not indicate the real segmentation, as shown by the nerve ganglia and segmental organs within. Leeches attach themselves to fishes or other animals, and puncture the skin by means of three sharp radiating teeth, and penetrating the blood vessels they suck out the blood, filling themselves to engorgement. The alimentary canal contains a number of saccular pockets corresponding to the body segments, and posteriorly there are long, paired lateral extensions. These pockets are filled with blood when the leech has had an opportunity to gorge itself, and on this store the animal may survive for a long period of time. The circulatory system is rather more complicated than in the earthwork, as in addition to the dorsal and ventral vessels there are large lateral vessels, in which the flow of blood is backward. The branching vessels, or so-called hearts, occur in several segments. The nephridia are distributed in segments six to twenty-two, the openings from these being distinct round apertures close to the

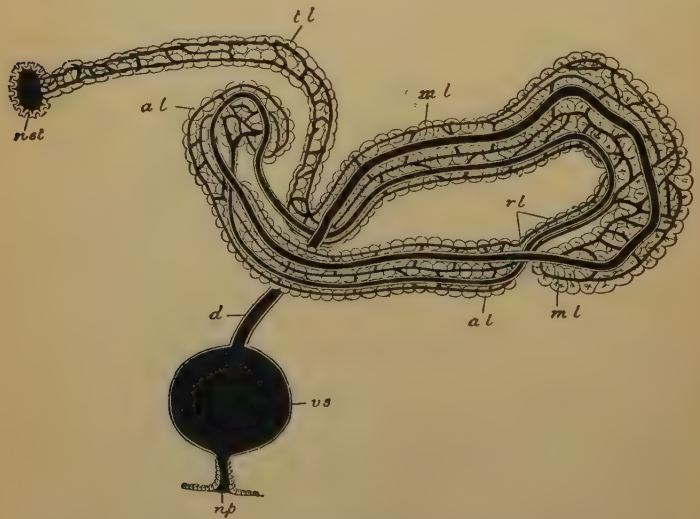


FIG. 73. — Nephridium of the medicinal leech. *a.l*, apical lobe; *m.l*, middle lobe; *np*, nephridiopores; *nst*, nephrostome; *r.l*, recurrent lobe; *t.l*, testis lobe; *vs*, vesicle; *vs.d*, vesicle duct. (After Bourne.)

margin of the ventral side. The ovaries are located anteriorly in segment eleven, and each ovary has a short oviduct connecting below with the opposite duct, and the two form the vagina, which has its external aperture in the mid ventral line. The testes are separated into nine parts, occurring in segments twelve to twenty, and each one gives off a short duct which connects with a longitudinal vas deferens, these enlarging in segment ten, and forming a coil, the **vesicula seminalis**, which is continued forward in a dilated **ductus ejaculatorius**. Each duct passes to the base of the elongate external intromittent organ attached to the ventral surface of the tenth segment.

Common species of leeches occur attached to fishes, turtles, and other aquatic animals, and must draw somewhat seriously upon them for their food supply. The so-called bloodsuckers, which frequently attach to persons when bathing, are some of these leeches and are at times a serious nuisance. The medicinal leech in former times was used for drawing blood in medical practice. While this still is practiced in certain localities, it has been abandoned in practically all the more enlightened and progressive regions, and the sight of numerous leeches in glass jars kept ready for surgical operations is now a rare one.

TROCHELMINTHES

Class Rotifera

The members of this group are minute aquatic forms which have a peculiar structure upon the head by means of which they travel and from which they get the name of "wheel animalcules." The body is composed of three fairly distinct regions, the anterior one being the head and the central one the trunk region, followed by a posterior process sometimes elongate, but frequently shortened, and in some cases used as a means of attachment. The cilia of the head region are located on what is termed the **trochal disk**, and this consists of two or more lobes, and the cilia on the

opposite lobes usually rotate in opposite directions, and their combined movement results in driving the animal in a forward direction. Within the trochal disk is a small mouth opening and

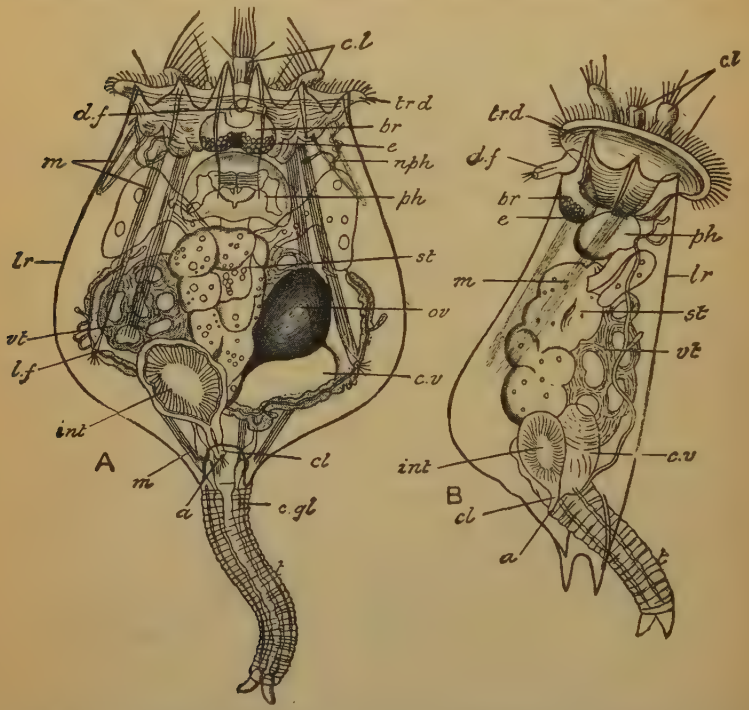


FIG. 74. — **Brachionus rubens.** A, from the dorsal aspect; B, from the right side. *a*, anus; *br*, brain; *d.f*, dorsal feeler; *c.gl*, cement gland; *cl*, cloaca; *c.l*, ciliary lobes; *c.v*, contractile vesicle; *e*, eye spot; *int*, intestine; *lr*, lorica; *l.f*, lateral feeler; *m*, muscular bands; *nph*, nephridial tubes; *ov*, ovary; *ph*, pharynx; *st*, stomach; *t*, tail; *tr.d*, trochal disk; *vt*, vitellarium. (After Hudson and Gosse.)

this leads to a peculiar grinding organ, the **mastax**, composed of two or three hard chitinous pieces, which press upon each other with a rotary motion, so that materials passing between them are ground up and fitted for digestion. The stomach is a distinct enlargement of the canal and is followed by a slender intestine

which opens exteriorly near the base of the tail in a small anal opening. Organs of circulation and respiration are wanting, but there is a distinct excretory organ on each side, its duct opening into the cloaca. The nervous system is represented by a ganglion, or brain, situated dorsally above the pharynx. On the surface of this ganglion is a single pigment spot called the eye. The sexes are distinct, and the males are generally much smaller and less developed than the females, in some cases the alimentary tract being entirely wanting. Rotifers are capable of enduring extreme dryness. Two types of egg occur, larger ones giving rise to fe-

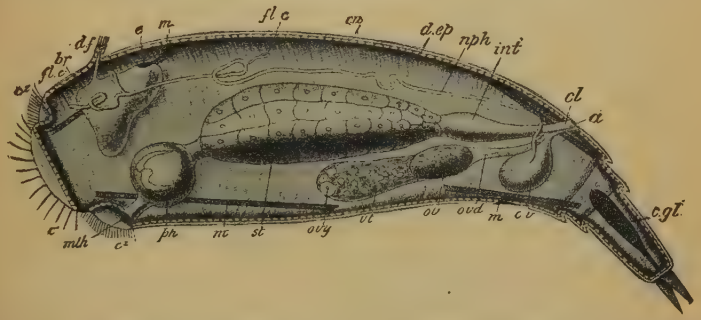


FIG. 75. — Diagram of a rotifer. *a*, anus; *br*, brain; c^1, præ-oral; c^2, post-oral circlet of cilia; *c.gl*, cement gland; *cl*, cloaca; *cu*, cuticle; *d.ep*, deric epithelium; *d.f*, dorsal feeler; *e*, eye; *fl.c*, flame cells; *int*, intestine; *m*, muscles; *mth*, mouth; *nph*, nephridial tube; *ov*, ovum; *ovd*, oviduct; *ovy*, ovary; *ph*, pharynx; *st*, stomach; *vt*, vitellarium. (After Parker and Haswell.)

males and smaller ones to males. It is assumed that both may develop parthenogenetically. In autumn, winter eggs, having very thick shells, are produced, and these require fertilization.

The rotifers abound in almost all bodies of fresh water and constitute a considerable element in aquatic life, and doubtless they furnish a large amount of food material for larger forms. Otherwise they have but little economic importance. They present a great variety of habit, many living as free-swimming forms near the surface of the water, others attached more or less constantly to the surface of aquatic objects, and still others becoming quite

distinctly attached and building up turret-like structures, within which they are protected and from the free end of which the trochal disk with its cilia is projected. Rotifers can be studied only by the aid of the microscope, but they form extremely interesting objects for study, and may be found in almost any water which may be examined.

The systematic position of the Rotifera is in doubt, and the position assigned them here need not be considered as an expression of their natural affinities. They show relationship to the Annelids in certain characters, but whether as primitive, generalized forms or as highly specialized, degenerate forms is an open question.

We may mention here also the groups **Gastrotricha** and **Dinophilea**, which are also uncertain, but may be associated with Rotifera on the basis of certain characters.

The **Chætognatha,** another perplexing group, may be named, but will not be further discussed. For all these divisions the detailed discussion of affinities may better be reserved for more advanced courses.

CHAPTER VII

MOLLUSCOIDEA

Class Polyzoa

The Polyzoans are aquatic animals, the larger part being marine, but a considerable number of fresh-water forms are known, and some of these are remarkably beautiful and interesting objects well worth study. They are attached animals, usually forming colonies by budding or division, so that a large number of apparent individuals may be connected, and in reality the product of a single embryo. The structure is somewhat complicated, largely as an adjustment to the fixed condition, and the whole animal shows most distinctly the results of sedentary life. The bodies are usually in a case sometimes gelatinous or chitinous, these being attached directly or with other members of the colony to the base of support. Within this case the larger part of the body is hidden, but from the free end there may be projected a large fleshy lobe called **lophophore**, which bears a large number of ciliated tentacles. The lophophore and tentacles may be extended and vibrate freely in the water, or if disturbed may contract suddenly within the case. The mouth opening is within the circle of tentacles and connects with a short esophagus and stomach, which is bent upon itself so that the intestine runs toward the head end and opens externally either within or just outside of the circular ring of tentacles. The stomach is usually anchored to the wall of the body by a short tendon (funiculus). Organs for circulation, respiration, and excretion appear to be wanting, but movements of the body fluid occur within the body space, and nutritive fluids are doubtless absorbed through the cellular tissues. The nervous system consists of a distinct ganglion lying dorsal to the pharynx,

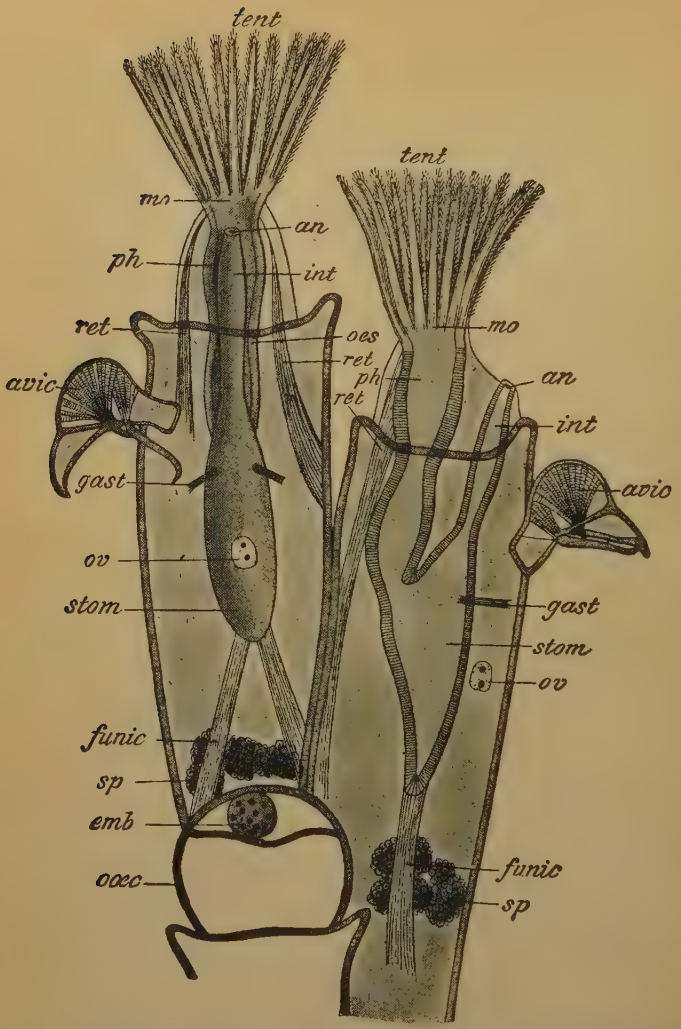


FIG. 76. — **Bugula avicularia.** Two zooids, magnified. *an*, anus; *avic*, avicularia; *emb*, embryo inclosed in the œcium; *funic*, funiculus; *gast*, muscular bands passing from the stomach to the body wall; *int*, intestine; *mo*, mouth; *oœc*, œcium; *œs*, esophagus; *ov*, ovary; *ph*, pharynx; *ret*, parietovaginal muscles; *sp*, spermatidia; *stom*, stomach. (After Parker and Haswell.)

and from this nerve fibers extend to various parts of the body. There are no distinct organs of special sense, nevertheless they show a very distinct sensitiveness, the tentacles and lophophore contracting with wonderful rapidity on the approach of any disturbing factor; and there seems to be a certain amount of trans-

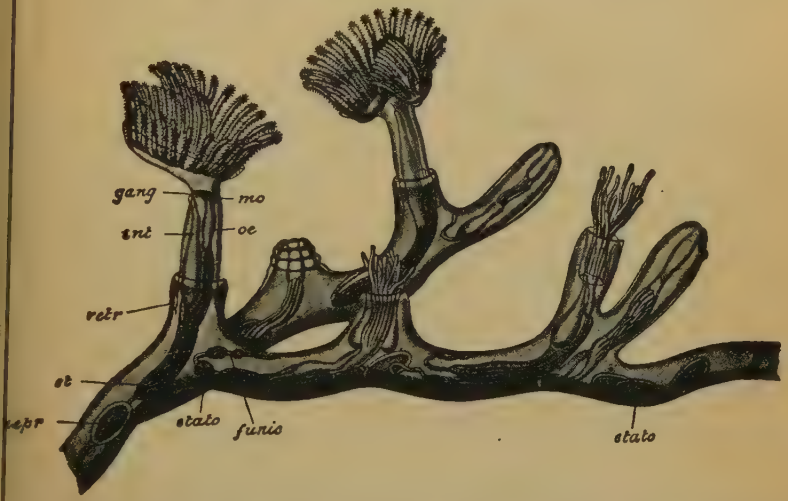


FIG. 77. — **Plumatella.** Portion of a colony magnified. *gang*, ganglion; *int*, intestine; *mo*, mouth; *œ*, esophagus; *repr*, reproductive gland; *retr*, retractor muscle; *st*, stomach; *stato*, statoblasts. (After Allman, from Parker and Haswell.)

mission of sensitiveness from one individual to another, since the irritation of one individual appears to result in almost simultaneous contraction of all the members of the colony.

Reproduction is specialized as in the case of almost all sedentary animals, there being frequently two distinct modes of multiplication, one by the ordinary sexual reproduction resulting in the development of eggs and the growth of embryos, and the other consisting of division, resulting in the formation of colonies including large numbers of individuals, one or any number of which may continue in existence if separated from the other members

of the colony. There is also an adaptation to the conditions of fresh-water life by the formation of bodies called **statoblasts**, which are formed during the later part of the season and which develop into a new colony the following year without the formation of true eggs or development of primary germ layers. The statoblasts are flattened, circular bodies protected by a dense chitinous covering or possessing usually sharp hooks or spines on the margin. These, no doubt, serve to attach the statoblast to some suitable object, so that it may retain its position and not be carried away by currents of water. Marine forms of polyzoans, while abundant and constituting in some places an important factor in the mass of life, do not possess any direct economic importance. Most of them are minute and are noticeable only on account of the large growths formed by the colonies attached to seaweeds or other marine objects. The fresh-water forms are too insignificant in numbers to constitute a very important factor except as food for other organisms or as predatory forms capturing minute animals. The colonies, which may be spread over a flat surface, as, for example, the under side of a floating board or plank, as shown in the accompanying plate, must be looked for in rather quiet water, and the large *Pectinatella magnifica*, which secretes a great mass of gelatinous substance and builds up a globular or oval mass sometimes eight to ten inches in diameter, is found attached to submerged sticks, cables, piling, etc., but quickly disintegrates after having reached the maximum of its growth for any particular season.

The Polyzoa are classified primarily on the basis of the position of the anal opening, those with the anus lying outside the lophophore being termed ectoprocta, while those with the anal opening within the circular part or tentacles are called endoprocta. The further division of the group is based on the characters of the cyst or attached appendages.

Some peculiar appendages occur connected with the cyst, the more striking of these being the device looking like birds' heads, called **avicularia**, which are capable of catching and holding ob-

jects which come near the body, possibly for the purpose of supplying food material. The **vibracula**, which are vibrating bristle-like bodies, possibly possess the function of defense.

Class Brachiopoda

The brachiopods were formerly included with the mollusks on account of the presence of a hard shell and bivalve form, but this shell is not formed on the same plan of symmetry as that of the true mollusks, being ventral and dorsal instead of right and left, and, moreover, the development of the embryo shows a very distinct difference, and at present the group is given an entirely separate rank. The species are all marine and not particularly abundant at the present time, although they flourished in enormous numbers in earlier geological periods. The shell consists of two valves, an upper and a lower, or dorsal and ventral, these being different in length and in the presence of the prolongation or beak on the ventral shell. Over this beak there extends a fleshy peduncle by means of which the animal is anchored to a rock or in mud or sand at the bottom. A considerable portion of the space within the shell is occupied by the branchial cavity formed by the shell and outer portions of the mantle, and within it are two coiled folds forming the lophophore, resembling in structure that of the polyzoans. At the base of these folds is the mouth opening, and the esophagus turns abruptly upward and extends into the stomach in the dorsal portion of the body. Posteriorly it turns downward and narrows into an intestine which in some forms extends forward to an anus just below the mouth, while in other cases it terminates in a blind sac without any external opening. The body fluid circulates in spaces within the body cavity and in channels running along the lophophore, within which the supply of oxygen is received. Respiration consists in the taking of oxygen from the currents of water drawn among the tentacles of the lophophore by the ciliary action. Excretion depends upon the action of small nephridial organs, which termi-

FIG. 78. — A fresh-water Polyzoon showing colony spread out in branching form on a board. Sandusky Bay. (From photograph by the author.)

nate at the base of the branchial space and which serve also as oviducts for passage of the ova. The nervous system consists only of a small ganglion next the esophagus, and forming a ring

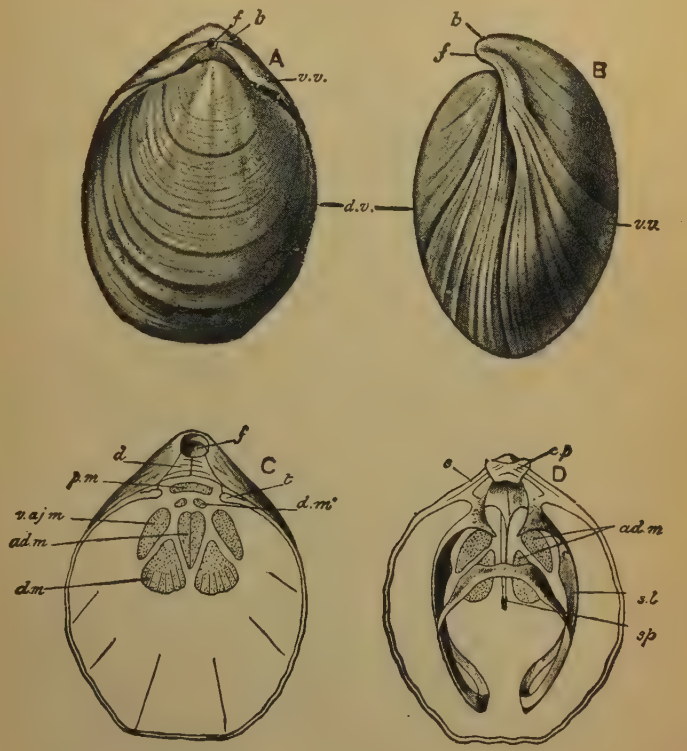


FIG. 79. — **Magellania flavescens.** A, the entire shell from the dorsal aspect; B, from the left side; C, interior of ventral valve; D, of dorsal valve; *ad. m*, adductor impressions; *b*, beak; *c.p*, cardinal process; *d*, deltidium; *d.m*, divaricator impressions; *d.v*, dorsal valve; *f*, foramen; *p.m*, protractor impressions; *s*, tooth socket; *s.l*, shelly loop; *sp*, septum; *t*, tooth; *v.v*, ventral valve. Australian seas. (After Davidson, from Parker and Haswell.)

around it. Organs of special sense are not represented. The reproductive organs lie in the posterior part of the body cavity,

and the products are discharged into the cavity, the ova being carried through the nephridial ducts into the branchial cavity.

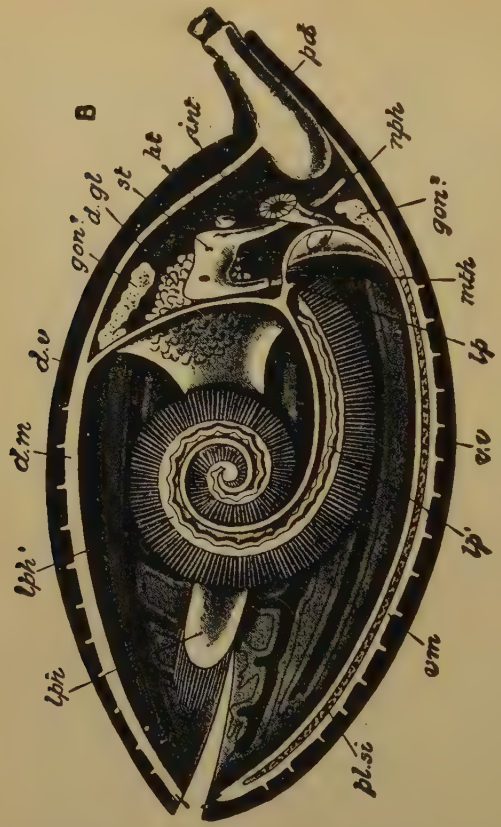


FIG. 80. — **Magellania lenticularis**. Sagittal section of the entire animal. *d.gl*, digestive gland; *d.m*, dorsal mantle lobe; *d.v*, dorsal valve of shell; *gon*^{1}, *gon*^{2}, gonads; *ht*, heart; *int*, intestine; *lp*, *lp*^{1}, lip; *lph*, lophophore; *lph*^{1}, its coiled process; *mth*, mouth; *nph*, nephridium; *pd*, peduncle; *pl.si*, pallial sinuses; *s*, setæ; *v.m*, ventral lobe of mantle; *v.v*, ventral valve of shell. New Zealand coast. (After Parker and Haswell.)

The brachiopods constituted a very large factor in oceanic life in earlier times, if we may judge by the immense number of deposits

formed by their shells, and their numbers seem to have declined somewhat in proportion as the mollusks have increased. At the present time they form a very inconspicuous part of the animal life of the ocean and cannot be assigned any special importance from an economic standpoint. The large quantities of limestone formed from their shells, and which in some instances are used very extensively in the manufacture of lime, gives a commercial value to those that existed in the past. Their study belongs, perhaps, more directly with paleontology than with zoology, as their occurrence is used as one of the criteria in determining the age of different rock strata.

Their embryological history is of special interest, since it is from this that we get some clew as to their affinities. It is generally conceded that their relationship is closer to the annelids than to the mollusks, but they represent a distinct specialized branch and were doubtless differentiated from the annelidan stock at a very remote period. Their fossils occur in forms indicating that the group was well established as far back as Cambrian and Silurian.

The basis of classification is found in the articulation of the shells and in the character of the alimentary tract. In one division the shell valves do not articulate closely and are held to the body simply by the mantle surfaces, and in these the alimentary tract is not provided with the external anal opening. In the other group the shell valves are hinged together, and the alimentary tract extends to the branchial cavity. The former group includes *Lingula*, a genus which is very remarkable from the fact that it is represented in all ages of the earth's history from the Paleozoic to the present time. The *Lingula pyramidata* occurs along our eastern coast, more particularly from Chesapeake Bay southward to the Gulf. The Terebratula, which represents the other division, is found in northern waters attached to rocks, especially along the coast of Massachusetts and Maine.

CHAPTER VIII

ECHINODERMATA

In the Echinoderms we have a branch of animals which is very distinct from all other groups. The group has taken on a very distinct feature of structure and a phase of development which is not represented in any other group.

Echinoderms, of which we have the most familiar examples in the starfish, sea urchin, and sea cucumber, are strictly marine animals, and are recognized and characterized particularly by a radiate structure.

Taking the starfish as an example, we have an animal that has this star-shaped structure, with arms radiating from a common center. The color of the preserved specimen is somewhat changed, but flexible arms, soft feet, and other characteristics are much as found in life. The radiate condition is secondary, and may be seen to be superimposed upon a bilateral symmetry. In order to get the parts of the animal properly placed, we need to start with some landmark. The mouth is on the under side with the animal in normal position, and this side is called the oral side and the opposite side the aboral. The divergent arms are called rays. While the rays appear to be similar, they have a certain definite arrangement with reference to certain organs. The **madreporite** is not located in the center, but in the angle between two arms, and through it we can divide the animal into equal parts. The two arms including the madreporite form the **bivium**, the three opposite, the **trivium**. On the surface, we have a number of rather short, stiff spines, little projections which give it a rough appearance, and also minute pincer-like organs called **pedicellariæ**. Taking the oral side, there are several points to notice particularly.

There are a series of furrows that radiate from the mouth, and these are called ambulacral furrows. These radiate out to the end of each arm, and include four series of flexible, soft structures that are called ambulacral feet. By contraction of its feet the starfish may drag itself along from one point to another, or, if turned over, these feet can be extended and serve to right the animal. It really creeps in a sluggish manner and drags its body along by contraction of its feet. These are parts that are most evident on the exterior. One thing to be noticed here is the arrangement of the parts of the skeleton, which serve to form the walls of the furrow. This is made up of a series of closely fitting plates arranged side by side and between which there are openings so that ambulacral feet project through. The other skeletal parts are not arranged so regularly, but extend out from the sides, reaching and connecting irregularly with aboral plates, forming the upper surface of the body. The internal anatomy of the starfish is quite different from any of the animals we have heretofore studied. Some organs agree with those, but others are very different. The alimentary tract has a very short esophagus, which expands into a large muscular stomach. This is adapted to its particular kind of food. The starfish feeds upon oysters,

FIG. 81. — **Starfish.** General view of the ventral surface, showing the tube feet. (From Leuckart and Nitsche's Diagrams.)

and to secure these it projects the stomach and inserts it between or over the valves of the oyster. The stomach is short, but

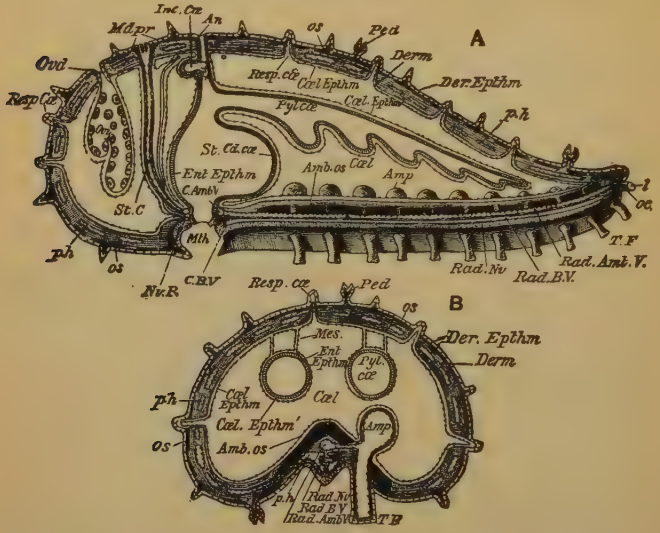


FIG. 82. — Diagrammatic sections of a starfish. A, vertical section passing on the right through a radius, on the left through an inter-radius. The off-side of the ambulacral groove with the tube feet (*T.F*) and ampullæ (*Amp*) are shown in perspective. B, transverse section through an arm. The ectoderm is coarsely dotted, the nervous system finely dotted, the endoderm radially striated, the mosoderm evenly shaded, the ossicles of the skeleton black, and the cœlomic epithelium represented by a beaded line. *amb.os*, ambulacral ossicles; *amp*, ampullæ; *an*, anus; *C.Amb.V*, circular ambulacral vessel; *C.B.V*, septum of ring blood vessel; *Cd.cæ*, cardiac cæca; *Cœl*, cœlome; *Cœl.Epthm*, cœlomic epithelium; *Der.Epthm*, deric epithelium; *Derm*, mesoderm; *Ent.Epthm*, enteric epithelium; *Int.cæ*, intestinal cæca; *Mdpr*, madreporite; *Mes*, mesentery; *Mth*, mouth; *Nv.R*, nerve ring; *oc*, eye; *os*, ossicles of body wall; *ovd*, oviduct; *Ped*, pedicellariæ; *ph*, perihæmal spaces; *pyl.cæc*, pyloric cæca; *Rad.Amb.V*, radial ambulacral vessel; *Rad.B.V* points to septum in the radial blood vessel; *Rad.Nv*, radial nerve; *Resp.cæ*, dermal branchiæ; *St*, stomach; *St.c*, stone canal; *t*, tentacle; *T.F*, tube feet. (From Parker's *Biology*.)

muscular, and has pouches which extend out into the arms and from which there are quite numerous little side pouches. The secretion from these pouches or glands is poured into the stomach,

and assists in digestion. The food is distributed from the stomach walls to all parts of the body, and there is not a very marked circulatory system. Running along the stone canal there is a little

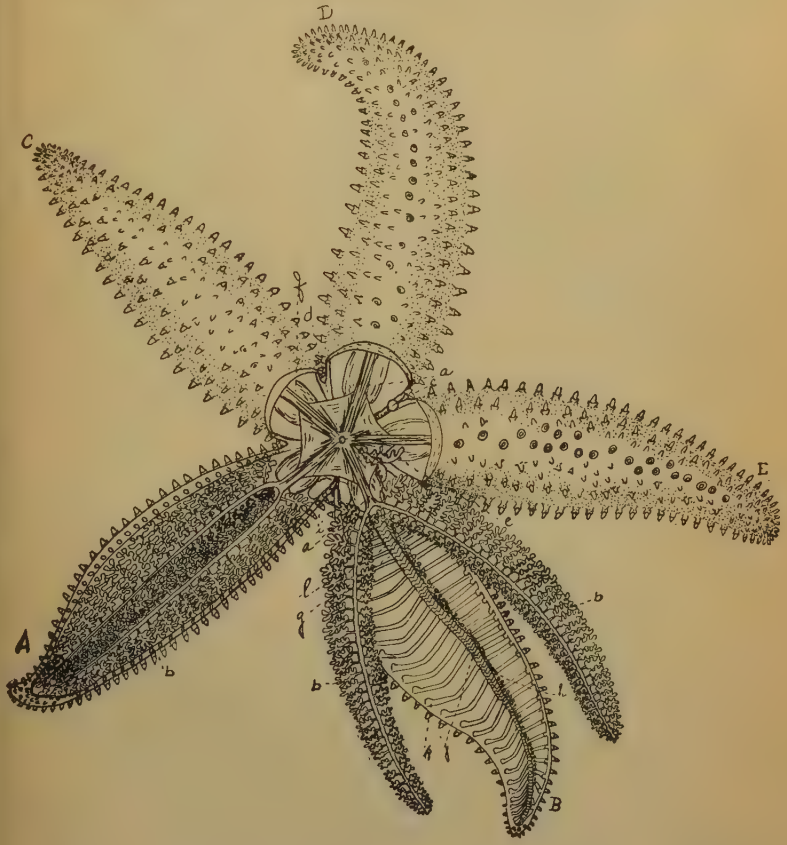


FIG. 83. — **Starfish, Asterias.** A, anterior ray with aboral surface cut away; B, right trivium; C, left trivium; D, left ray of bivium; E, right ray of bivium; *a*, duct from hepatic cæca to stomach; *b*, hepatic cæca; *c*, madreporic body; *d*, inter-radial partition; *e*, respiratory tree; *f*, hepatic cardiac pouch of stomach; *g*, vertebral ridge; *i*, reproductive body; *h*, ampullæ; *j*, ambulacral plates; *k*, interambulacral plates; *l*, retractor muscles of cardiac pouch of stomach. (From drawing by Miss Freda Detmers.)

tube which is supposed to correspond to the blood vessels of other animals, and that sends vessels over the alimentary tract, and nutrition is distributed in that way, but it is not very closely connected with respiration. The water-vascular system starts from the madreporic plate, which is the external portion from which we suppose the water to enter. There is a little tube, the stone canal, which runs down to and connects with the ring canal, which surrounds the mouth. From that canal there are tubes that run out into the arms, so that water entering these tubes will be distributed along each of the arms, and from these radial vessels there are little vessels given off at the sides called lateral vessels. These supply the tubes which run down between the openings in the plates to the ambulacral feet, so that the water can be gradually forced down into them. These are filled with water and are under control of the nervous system, and in that way the action of the ambulacral feet is controlled. The muscularity of the feet forces the water out, thus retracting them, while forcing the water in extends the feet. There are also little sac-like structures within the skeleton, the **ampullæ**, from which water is forced into the tube feet. The function of this system is double, at least. It is used for locomotion, the changes of water pressure causing the sluggish movements of the animal, and it provides for the respiration, the water that circulates in the system carrying oxygen to the different parts of the body. The nervous system is almost external in its position, the ganglia lying in a ring surrounding the mouth, and there are radial nerves extending out within each arm and just beneath the epidermis to the ampullæ and the ambulacral feet. These structures are all under control, and the contraction is governed by the nervous system. Aside from the water-vascular system there is another structure which may have to do with respiration, which is called the respiratory tree. The respiratory tree is connected with the digestive tract near the upper surface of the disk, and from that is given off water which exudes into the body cavity, and probably serves there as some factor in respiration, although it is much smaller in the

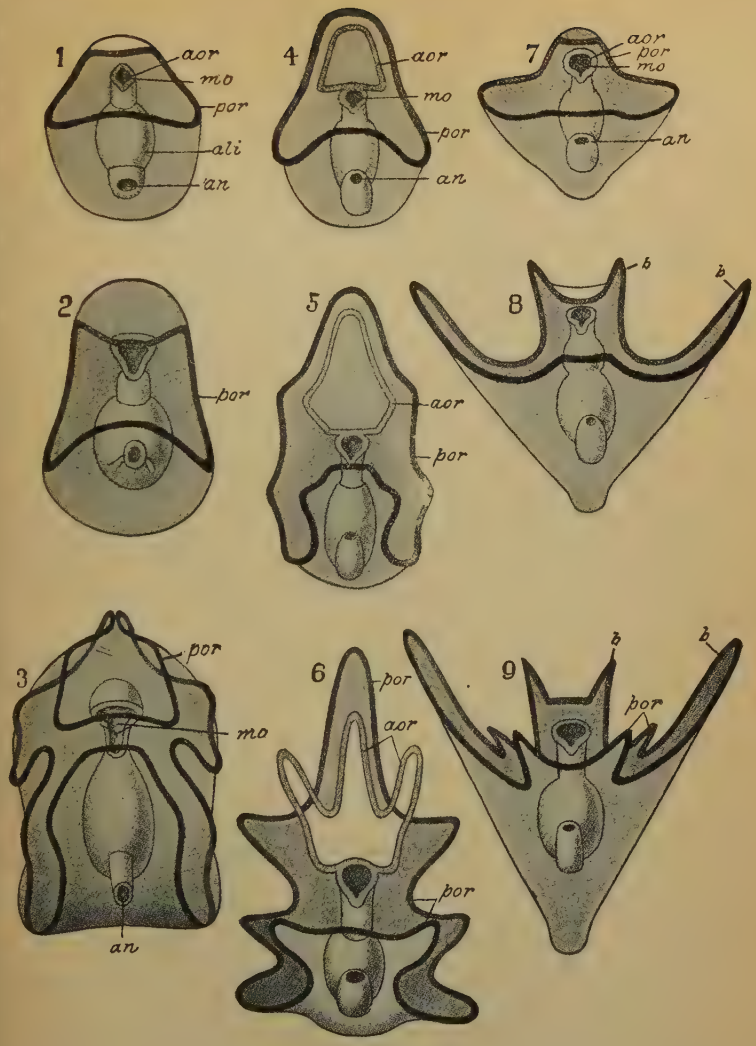


FIG. 84. — Diagrams of the development of the larvæ of Echinoderms. *1*, primitive form of Echinoderm larva; *2* and *3*, development of an Auricularia (Holothuroidea); *4*, *5*, and *6*, development of a Bipinnaria (Asteroidea); *7*, *8*, and *9* development of a Pluteus (Echinoidea and Ophiuroidea). (From Leuckart and Nitsche's Diagrams.)

starfish than in other Echinoderms. It is interesting to compare this with the sea cucumber, where the madreporic plate is internal on the alimentary canal, and must take up its supply of water from the interior. That probably is a secondary modification.

Jennings has shown that the starfish possesses a quite high degree of ability to respond to change of treatment or to accommodate itself to its immediate surroundings and conditions. He interprets this as a phase of memory or ability to be taught. Such an ability contrasts with those forms in which there is an invariable response to any given stimulus.

The reproductive organs are located near the angle of the arms, and the glands of male and female are in separate individuals but are located in the same position. The ovaries, when filled with eggs, are considerably larger than the testes. In the starfish there are five pairs of glands, the openings from these being in the angle between the arms. The development is one of the most remarkable things about the Echinoderm, and is particularly significant with regard to their relation to other kinds of animals. When the starfish hatches from the egg, it is very minute, but is totally different in appearance from the adult form, and the most significant thing about it is doubtless that it is very distinctly bilaterally symmetrical, and there is no trace of the radial symmetry. A little later it resembles the early stage of a larval form, such as the annelids have, or an early stage of some other worm-like form, and still later it changes its form from the bilateral symmetry, and is so different in that stage that it was at first described as an entirely distinct animal and was given a special name. But after it has gone through several steps of growth, it begins to develop within by the growth of an entirely distinct individual, which finally absorbs or takes up all the tissues and finally assumes the radial form, with very short arms, and from that condition it gradually grows to the adult stage. This general plan of development is true of all Echinoderms. The larvæ of the starfish, sea urchin, and sea cucumber, etc., are very much

alike, but when they become adult, they are very distinct-looking forms. This indicates that these forms of echinoderms are most closely related, but perhaps the most significant thing is that bilateral stages show so distinctly that symmetry has been modified from the bilateral ancestors.

The question will naturally arise as to what induced these animals to change. The reason would seem to be that some time in the past their ancestors became sedentary and that the result of adaptation to the attached condition changed them to this radial form. But these are not now fixed animals, and the thing that this cycle seems to signify is that they are descendants of stalked forms. They pass through this stage and later reach a free condition. The crinoids are largely stalked and have long arms and are called sea lilies. Now there are certain kinds of crinoids which start out with bilateral symmetry and then change to the radial form, and are stalked, and later leave their stalked condition and become free like the starfish.

It should be especially noted that, while echinoderms show an ability to change back from a sedentary to a free form, they do not by any means resume the primitive characters of the original free ancestors.

Class Crinoidea

The Crinoids include some remarkably beautiful forms occurring in deep seas, but the great majority of the species are extinct. They were enormously abundant during early geological epochs, and their fossils are found in great quantities, especially in the Silurian and Devonian deposits. The more typical forms are stalked, the rays or branching arms forming a large flower-like extension at the extremity of the stalk, which in some species is from one to three or four feet in length. The study of these forms is more closely related to paleontology, but it is interesting to note that they present the same five-rayed condition and distribution of organs and stages of development found in the more

modern group. One of the living species (*Antedon*) passes through a bilaterally symmetrical larva stage, later becomes attached and develops a short stalk, but still later separates from the stalk, and becomes a free individual, suggesting forcibly the route by which the majority of radiate forms have come; that is, that the five-rayed condition was derived from the bilaterally symmetrical

FIG. 85. — **Antedon.** Side view of entire animal. European coasts. (From Leuckart and Nitsche's Diagrams.)

ancestral form as a result of attachment and sedentary habit, and that this structure became so thoroughly impressed upon the organism that when the sedentary condition was broken away from, the radiate condition still persisted.

The calcareous secretion of the stalk and rays has contributed largely to the formation of rock strata, but otherwise the group has but slight economic importance.

FIG. 86. — **Metacrinus interruptus.** (After P. H. Carpenter.)

Class Asteroidea

This class includes the starfish and allied forms in which there is a set of arms, five or some multiple of five, the stomach extending into them and the madreporite external and located in the angle of the bivium. The group has been illustrated by the starfish, taken as a type for the Echinoderms. The common starfish, which is destructive in oyster beds, is the most important economic species.

Class Ophiuroidea

Brittle Star. — Members of this group resemble quite closely the starfish, but differ in having the arms much more slender and cylindrical and brittle, and the stomach and cæca confined to the region of the disk.

The ambulacral furrows are covered over by a series of plates. The ambulacral feet project from the sides of the arms, but are very much reduced in size, and of slight functional value. It would seem from their structure that they might have been derived from a starfish-like form, although in some respects, and especially in the early stages, they show closer affinities to the sea urchin.

From the economic standpoint they occupy a very unimportant position.

Class Echinoidea

This group consists of a considerable array of forms, and occupies a quite important place amongst the living forms of Echinoderms. They differ decidedly from the preceding groups in the absence of extended rays or arms and in the compact rigid external skeleton, which is usually surmounted by movable spines, in some instances of very large size. Their movements are sluggish, but in some members there is developed a quite distinct bilateral

symmetry in connection with the radial symmetry characteristic of the branch, and this may be considered as associated with a tendency to move in certain definite directions.

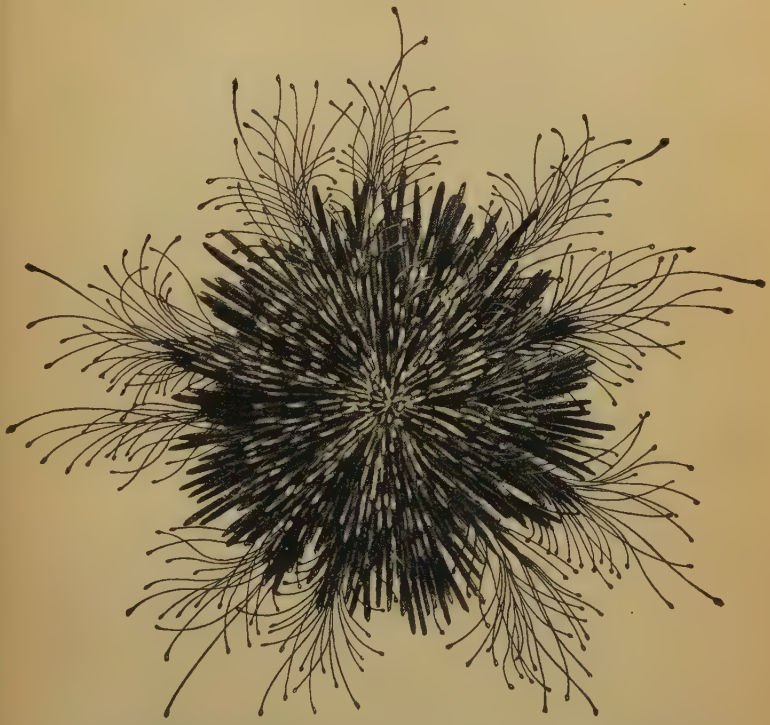


FIG. 87. — **Strongylocentrotus.** Entire animal, with the tube feet extended beyond the ends of the spines. (From Brehm's *Thierleben.*)

One of our most abundant and familiar examples on the Atlantic coast is the common sea urchin (*Strongylocentrotus dræbachiensis*). This has a diameter of one to two inches, and is covered with spines that are from one half inch to an inch in length, these spines being very numerous and forming a very complete protection for the animal. When removed, the body of the urchin is seen to be of

a flattened hemispherical form, the surface marked by a distinct oral area within which the teeth may be seen projecting, surrounded by a rather flexible oral disk. Opposite this on the aboral side is a much smaller flexible disk, including the anal open-

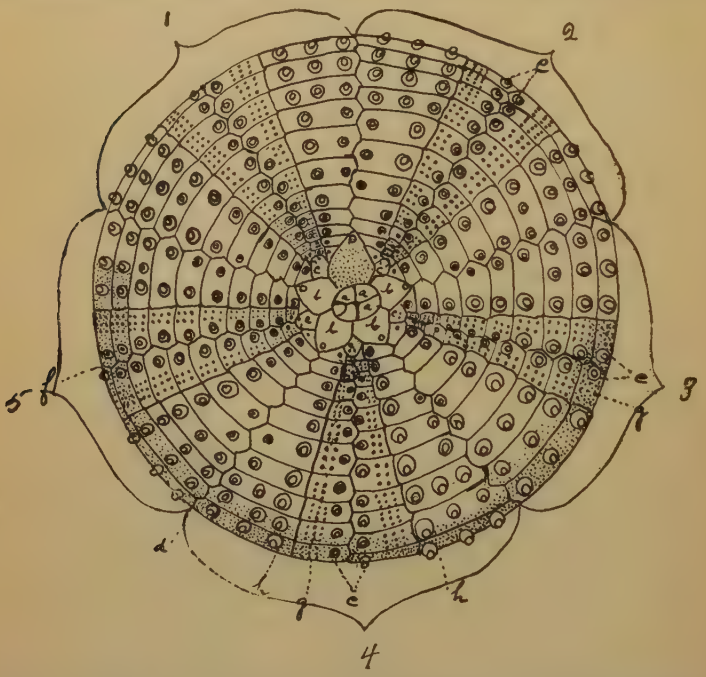


FIG. 88. — Aboral view of **Sea Urchin** with spines removed. *1*, *2*, *3*, *4*, *5*, ambulacral zones; *a*, *a*, anal plates; *b*, *b*, genital plates; *c*, *c*, ocular plates; *d*, interambulacral plates; *e*, *e*, ambulacral plates; *f*, madreporite. (From drawing by Miss Freda Detmers.)

ing and surrounded by two sets of five plates, one set representing the sensory termination of the radial nerves and termed the ocular plates; the others perforated by the genital pores and termed the genital plates. One of these is minutely perforated and constitutes the madreporic plate opening into the stone canal. Around the sides of the skeleton are ten distinct areas of plates, those

which are perforated for the passage of the ambulacral feet being called the ambulacral plates, and the intervening ones arranged in double series and bearing the articular knobs of the larger spines, termed the interambulacral. Of these the ambulacral plates may be considered as corresponding to the plates of the same name in the starfish, but it is especially to be noted that the radial vessels of the water-vascular system lie within these plates instead of exterior to them. The surface is provided with minute pedicellariæ which are similar to those of starfishes except in having three or four jaws instead of two. The ambulacral feet are capable of great extension, so that they may reach some distance beyond the ends of the spines and serve to attach the animal and enable it to creep or to roll itself over.

Internal Anatomy. — Internally the sea urchin differs considerably from the starfish, the alimentary canal beginning with a complicated masticatory structure, the "Aristotle's lantern," the five radial teeth of which project from the mouth opening. The esophagus broadens into a long capacious stomach, which curves around the body, then bends upon itself, returning to about the same point, then extends in a narrowed intestine to an anal opening in the aboral disk. The water-vascular system consists of the stone canal, which is not calcareous, extending from the madreporic body to the ring canal which lies around the inner part of the Aristotle's lantern, and from which radial vessels pass downward to the skeletal wall, and thence within the skeleton along the ambulacral plates, giving off lateral vessels which supply ampuliæ and ambulacral feet. Polian vessels also arise from the ring canal. The nervous system consists of the oral ring, including five ganglia lying close to the surface of the oral disk and giving off five radial nerves which parallel the radial vessels and supply lateral nerves to ampullæ and ambulacral feet, and terminate in the ocular plates of the aboral disk.

Noting condition of water-vascular system and nervous system, the parts of the sea urchin may be roughly compared to a starfish in which the rays have been brought together over the aboral disk,

so that the ends of the arms and eye spots are brought near together. The reproductive organs are five in number and open through small apertures in the genital plates.

Class Holothuroidea

Sea Cucumber. — These differ decidedly from the other groups of the Echinoderms, having a leathery, flexible body wall, and an elongated form which corresponds with the greater length from oral to aboral parts. The leathery wall includes minute calcareous plates, or spicules, which may be looked upon as remnants of calcareous skeletons of other groups. They often show complex forms, such as perforated plates, anchors, star-shaped bodies, etc. From the surface of the body project flexible ambulacral feet, sometimes irregularly distributed over the surface, in other cases arranged in definite rows; in some forms the rows are approximated on one side, which becomes the under side; in some groups entirely wanting; but in all of the forms there is added to the water-vascular system of the other groups a series of oral feet or tentacles surrounding the mouth, sometimes very beautifully branched.

The alimentary canal coils upon itself, being usually one and one half or two times as long as the body, and from the cloaca near the anal opening there arises a large, much-branched respiratory tree from which water taken in at the anal opening is exuded into the body cavity. The madreporic plate is located internally on the wall of the alimentary canal, and connects by a short stone canal with the ring canal surrounding the mouth, from which arise numerous radial vessels, the oral tube feet, or tentacles, and large Polian vessels.

Presumably, water to supply the water-vascular system is derived from the respiratory tree and taken in through the madreporic body. Within the walls of the body are five strong muscular bands which serve to contract the body. The reproductive organ consists of a single gland, the opening of which is near the oral end.

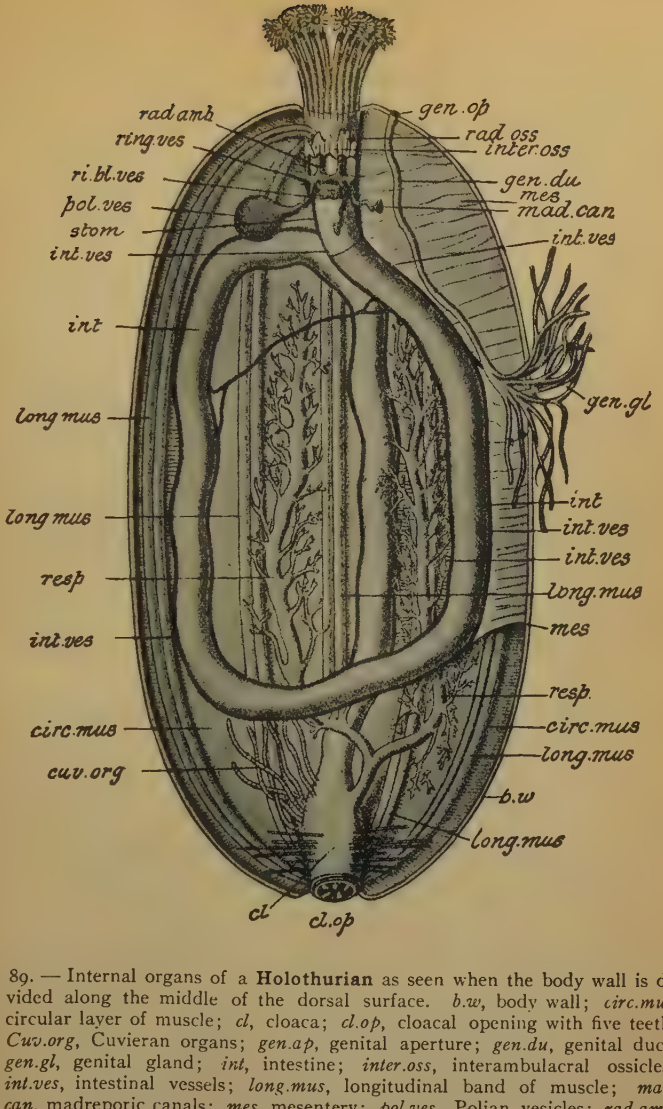


FIG. 89. — Internal organs of a **Holothurian** as seen when the body wall is divided along the middle of the dorsal surface. *b.w*, body wall; *circ.mus*, circular layer of muscle; *cl*, cloaca; *cl.op*, cloacal opening with five teeth; *Cuv.org*, Cuvieran organs; *gen.ap*, genital aperture; *gen.du*, genital duct; *gen.gl*, genital gland; *int*, intestine; *inter.oss*, interambulacral ossicles; *int.ves*, intestinal vessels; *long.mus*, longitudinal band of muscle; *mad. can*, madreporic canals; *mes*, mesentery; *pol.ves*, Polian vesicles; *rad.amb*, radial ambulacral vessel; *ri.bl.ves*, ring blood vessel; *resp*, respiratory trees; *ring.ves*, ring vessel of the ambulacral system; *stom*, stomach. (After Leuckart.)

Sea cucumbers live in muddy or sandy locations, generally in shallow waters, and swallow quantities of sand and mud, from which they extract such nutritive material as it may contain, and which assists in grinding the material into minute particles.

In their development the Holothurians agree with other Echinoderms except that in certain forms the larvæ develop directly

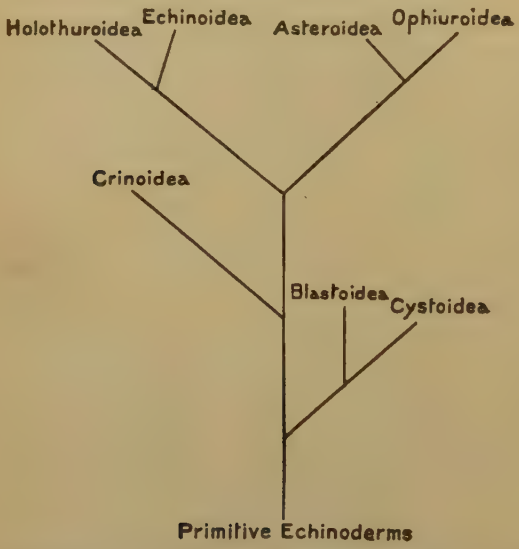


FIG. 90. — Diagram to illustrate the relationships of the classes of **Echinodermata**. (After Parker and Haswell.)

without a free-swimming bilaterally symmetrical stage. This would indicate specialization, and along with other features in the group suggests that the sea cucumbers are the most recent and most specialized echinoderms, though showing some degenerate characteristics.

CHAPTER IX

MOLLUSCA

THE mollusks are one of the large groups of animals containing several well-marked subdivisions and occupying a very definite sphere in nature. While they appear to be more widely separated from the Annelids than the Arthropods, they seem to be on the whole less highly specialized than the most highly organized Arthropods, and it seems proper to introduce them before the Arthropoda are taken up. Mollusks have a soft body, bilaterally symmetrical, without segmentation, and are in most cases protected within a hard, limy shell which may be divided into segments. It may consist of a single spiral valve or be bivalved, the valves lying on the right and left sides. The body is inclosed within a fold of the body wall called the **mantle**, by which the shell is secreted. The alimentary canal is continuous throughout the body, and often bent upon itself, so that the anal opening may be near the anterior or head region. There is usually a well-developed circulatory system, consisting of a dorsal heart and a distinct arterial system. Respiration is provided for by means of gills or lung cavities, which are related to the circulatory system. The excretory system consists usually of a pair of nephridial organs. The nervous system consists of ganglia distributed somewhat on the annelidan plan, except that the ventral chain of ganglia is modified or lost; and the organs of special sense are quite variously developed in the different subgroups.

The mollusks have been a conspicuous feature of animal life since the Palæozoic, apparently increasing in number, and there are now something like twenty thousand species known. The majority are marine, but a considerable number occur in fresh water,

and another considerable series are terrestrial in habit. From the distinctness of the different classes it is evident that they began to differentiate at an early period and that the evolution along different lines has resulted in very different types of structure. While each has reached a rather special or highly organized condition, Amphineura appear to preserve the more primitive characters. In a general way, it may be said that the Amphineura have maintained a rather simple creeping movement, that the snails have been modified by adaptation to particular movements, due to the mechanical strains resulting from positions in locomotion, and that the lamellibranchs have been adapted to burrowing or creeping through mud, and the cephalopods for free locomotion in water. The discussion of each of these groups may be taken up independently.

Class Amphineura

This group includes mollusks which may be considered as retaining more of the primitive characteristics than any of the other classes. They have an unsegmented body but usually a hard calcareous dorsal shell, which is composed of a number of overlapping plates, so that they have the appearance externally of being segmented. There is no elevation of the visceral organs, as in the gasteropods or cephalopods on the one hand nor a protrusion of ventral foot, as in the lamellibranchs. The bilateral symmetry is retained; a broad, flat foot provides for locomotion or attachment to surfaces of rocks. The mantle extends to the margin of the foot, and the dorsal shell covers the entire upper por-

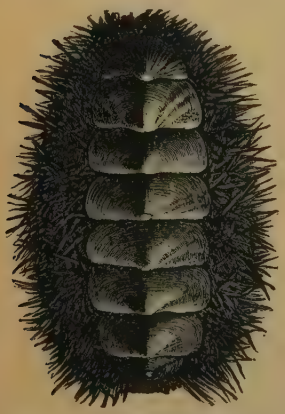


Fig. 91. — **Chiton spinosus.** Dorsal view. (From the *Cambridge Natural History.*)

tion and fits tightly to the surface upon which the animal rests. The mouth is situated at the anterior end, the alimentary tract passing through the body, the anal opening being located near the posterior end of the body. The circulation includes paired auricles, the ventricle being located in the posterior region and a slender artery running forward dorsally. Respiration is provided for by means of lateral gills, which are simple expansions of the body surface and in which the blood circulates. The excretory organs consist of paired nephridia which open posteriorly near the anal opening. The nervous system is peculiar in that the nerve cords pass from the cerebral and pedal ganglia as widely separated fibers to the posterior part of the body, where they connect with posterior ganglia. These parallel fibers are connected by numerous transverse threads, a condition which parallels in a way the nervous system of Nemertes and Peripatus.

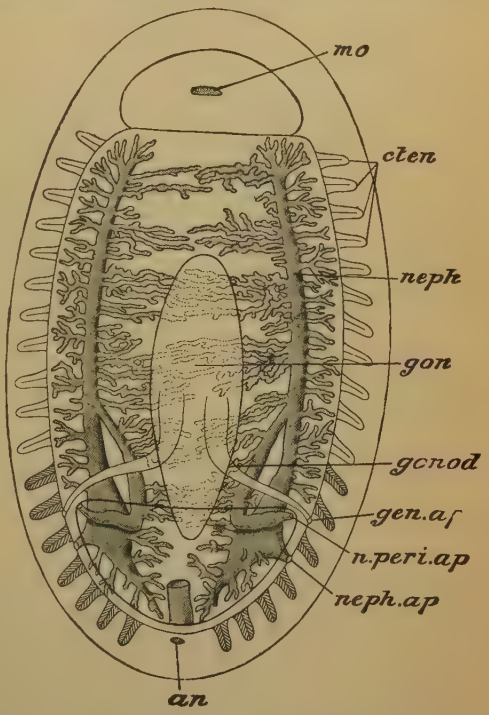


FIG. 92. — **Chiton**, nephridial and genital systems. *an*, anus; *cten*, ctenidia; *gen.ap*, genital aperture; *gon*, gonad; *gonod*, gonoduct; *mo*, mouth; *neph.ap*, nephridial aperture; *n.peri.ap*, aperture from nephridia to pericardium. (From Simroth, after Haller and Lang.)

The reproductive organs are simple, ovaries and testes being located in median line. The paired oviducts open externally near the nephridial openings.

The members of the group are of ancient derivation, probably to be considered as a persisting primitive group, rather small in number of species and possessing little economic importance.

Class Gasteropoda

This class, including snails, slugs, and whelks, is a rather complex group, departing quite widely from the primitive forms, and being modified especially by the torsion or twisting of a portion of the body, and by the elevation of the "visceral hump," which, in a large portion of the group, is included within a spiral shell. A close study, however, will show that there is a basic bilateral symmetry, and that the organs which are arranged unsymmetrically, or which may be suppressed, have been moved from the bilateral position in connection with the elevation and torsion of the visceral mass.

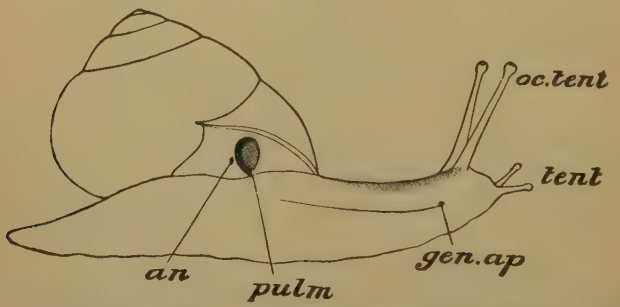


Fig. 93. — **Helix nemoralis.** *an*, anus; *gen.ap*, genital aperture; *oc.tent*, posterior eye-bearing tentacles; *pulm*, opening of pulmonary sac; *tent*, anterior tentacles. (After Pelseneer.)

There is, as a rule, an elongated flattened foot which may be retracted within the shell. The shell is lined with a mantle. The head projects anteriorly and bears two or four flexible tentacles which may be protruded or retracted at will, and on two of which,

either at the apex or near the base, are the simple eyes. The mouth opening is on the ventral anterior part of the head surrounded by fleshy lips, within which there is a hard, chitinous, toothed, rasping organ, the radula or odontophore. The esophagus is slender and connects with a crop or stomach in the visceral mass. The stomach is followed by the intestine more or less coiled, and extending forward to terminate in an anal opening on the right side of the body at a point which is outside the shell or mantle when the snail is extended. In the heart there is a large

FIG. 94. — Common snail, **Patula alternata**. (From drawing by D. Shira.)

ventricle from which blood is driven throughout the body and then is collected into sinuses, from which it is carried into the gills in the aquatic forms or to the lung in the air-breathing forms. From the respiratory organs the blood is collected into a large auricle which communicates by a valvular opening with the ventricle. Respiratory structures differ in different groups, the gills in aquatic forms being located in some cases anteriorly, in others on the hinder part of the body, while in the air-breathing forms there is a rather large lung cavity, the walls of which are densely lined with blood vessels and the opening into which is located beside the anal opening. It is withdrawn and concealed when the animal is contracted, but outside the mantle

margin when the animal is extended. In the air-breathing forms which are aquatic in habit, this lung opening is spread out at the surface of the water so that the air may be taken into the lung cavity and the respiration performed.

The excretory organs differ considerably in different groups, in some cases two nephridia being present, but in the majority of cases where there has been a torsion of the visceral mass, these nephridia are placed asymmetrically, and often one of them is completely suppressed. Commonly, the functional nephridia lie close to the heart, as a glandular and non-glandular portion, the

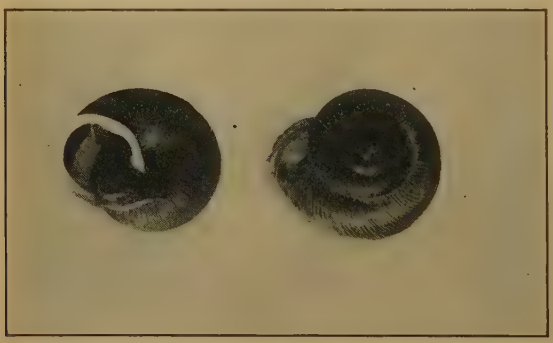


FIG. 95. — Snail shells, **Patula alternata**. (From photograph by the author.)

latter opening externally by an aperture through the mantle. The ganglia of the nervous system have the usual position with reference to the esophagus, but the posterior ganglia have been shifted in position by the torsion of the visceral mass, so that in some forms the parieto-viscerals occupy positions one in front of the other near the median line, or in extreme cases on the right and left sides of the body, but with the position completely shifted for the two ganglia, the right ganglion being pushed to the left side of the body and the left ganglion to the right side, as may be seen by tracing the nerve fibers. The eyes located on the tentacle are simple in structure, probably provided only for the distinction of light and darkness or the recognition of very imperfect images.

In some forms eyes are developed on other portions of the body, but the structure of these is usually different from that of those located on the tentacles. **Osphradia**, organs which are supposed to have an olfactory sense, are located at the base of the gills in those forms which are provided with branchiæ, and frequently occupy the same part of the body in forms in which the gills are suppressed.

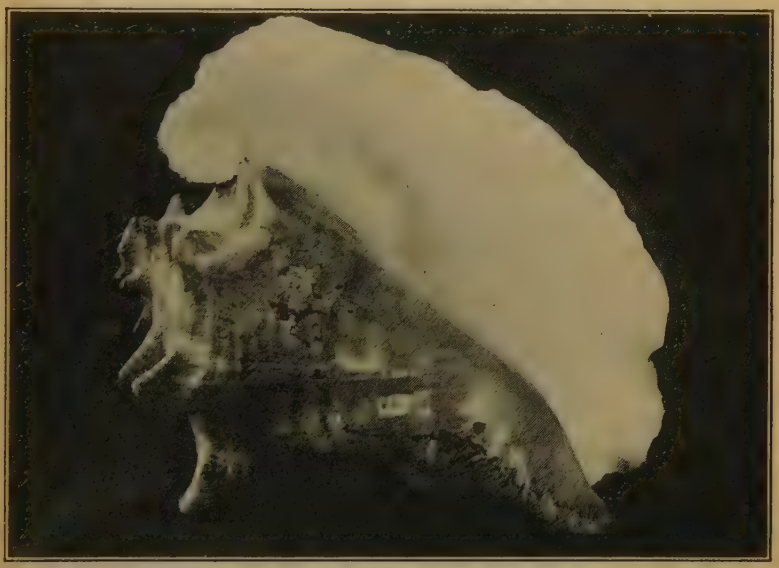


FIG. 96. — Conch shell. (From photograph by H. T. Osborn.)

In most of the gasteropods the sexes are not separate, but the large hermaphroditic glands produce both eggs and sperm, but at different times, and they are carried along different ducts to the external genital apertures lying at the sides of the head. Connected with the ducts are extensive glands which secrete a large amount of gelatinous material which envelops the eggs before their discharge. In some forms there is a complicated protractile organ, "Cupid's dart," which is discharged at the time of copulation.

The gasteropods are mostly sluggish, creeping animals, the broad ventral foot serving as a locomotor organ, and they depend upon the protection of the shell to avoid attacks of other animals and also in some cases to protect themselves against periods of dryness. The shell assumes very many different forms; it may be slightly or very extremely twisted, and the coil may be flattened or have an extended conical spire. While largely marine, large numbers are terrestrial in habit, and of the fresh-water forms a considerable number are air breathing, having lung cavities and being obliged to make frequent ascensions to the surface of the water for the purpose of securing fresh air. This air-breathing habit of the aquatic forms must be interpreted as indicating a secondary adaptation to aquatic life; that is, that they are derived from forms which were at some earlier period terrestrial in their habits and consequently adapted to lung breathing, but which, on account of some change in habit, became adapted to living under water, and not having organs for aquatic respiration, they were obliged to utilize the lung. As it seems certain that the terrestrial forms were derived originally from aquatic species that migrated from water, lost the gills and acquired lungs for air breathing, it appears that there has been a distinct cycle from aquatic through terrestrial back to aquatic life in those forms which have air-breathing organs connected with aquatic habit. It may be considered as possible that these aquatic air-breathing forms will in time develop secondary organs for aquatic respiration, and in this way avoid the necessity of reaching the air at frequent intervals for the purpose of respiration.

Class Scaphopoda

This is a small group which stands somewhat intermediate between the Gasteropods and Lamellibranchs, there being a single shell, tubular and slightly conical in shape.

They are bilaterally symmetrical, the head much reduced, the mouth being located at the tip of the proboscis and provided with an odontophore. The foot is rather slender, protrusible, and the

animals burrow in sand, occurring usually at some depth and at a distance from the shore line. All are marine, and none are of any special economic importance.

Class Lamellibranchia

This class includes a large section of the mollusks, and some of the most important of the entire group, such forms as the oyster,

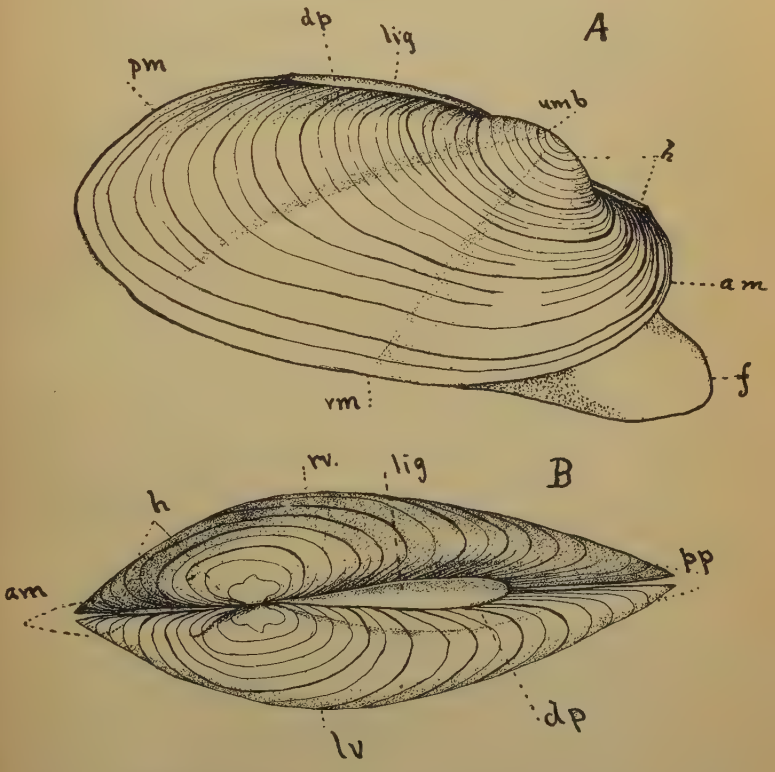


Fig. 97. — **Lampsilis luteolus**. A, view of right valve, exterior of shell; B, dorsal view. *am*, anterior margin; *f*, foot; *vm*, ventral margin; *pm*, posterior margin; *dp*, dorsal portion; *lig*, ligament; *umb*, umbo; *h*, hinge; *rv*, right valve; *lv*, left valve. (From drawing by Miss Freda Detmers.)

pearl oyster, and edible clam having very great economic importance. They are bilaterally symmetrical, provided with shells of two valves. The valves are located at the right and left sides of the animal, and the more common position is the vertical one, but in many species this habit has been changed to resting upon one side, and in some cases, as in the oyster, the valve which is beneath becomes firmly fixed to the surfaces of objects on which the animals rest.

The common fresh-water clam may be taken as a good example of the group, and in fact may serve as a general type for the entire group of mollusks. Our common fresh-water species are contained in the genera Anodonta, Unio, Margaritana, Lampsilis, etc.; but species in any one of these genera will serve about equally well as a type.

The shell, composed of two valves hinged along the dorsal line, and held together by a strong band of ligaments, shows exteriorly a thin leathery epidermis which is frequently somewhat worn at the part in front and occupying the most exposed portion of the dorsal side. This is called the **umbo**. Arranged in concentric lines around the umbo are the lines of growth, the more conspicuous ones of which represent the growth of different seasons, and from these an estimate of the age of the shell may be secured. At the margin of the shell the leathery epidermis gives place to a thin pearly or **nacreous** layer, which lines the entire inner surface of the shell, that part which is in direct contact with the mantle. On the inner surface will be noticed a distinct line, the pallial line, which runs parallel to the margin and which represents the line of union with the mantle. The anterior and posterior portions have large muscle scars indicating the points of attachment of the adductor muscles which pass between the two valves and serve, when contracted, to tightly close the shell. Between the epidermal and pearly layers is a prismatic layer which, like the pearly layer, is composed chiefly of carbonate of lime. The shell opens by tension of the ligamentous hinge, which, during the contraction of the muscles, is stretched above

the hinge. Shells allowed to dry will show a wider and wider spreading as the ligament contracts from the loss of moisture. The shells are tightly closed by contraction of the muscles, but

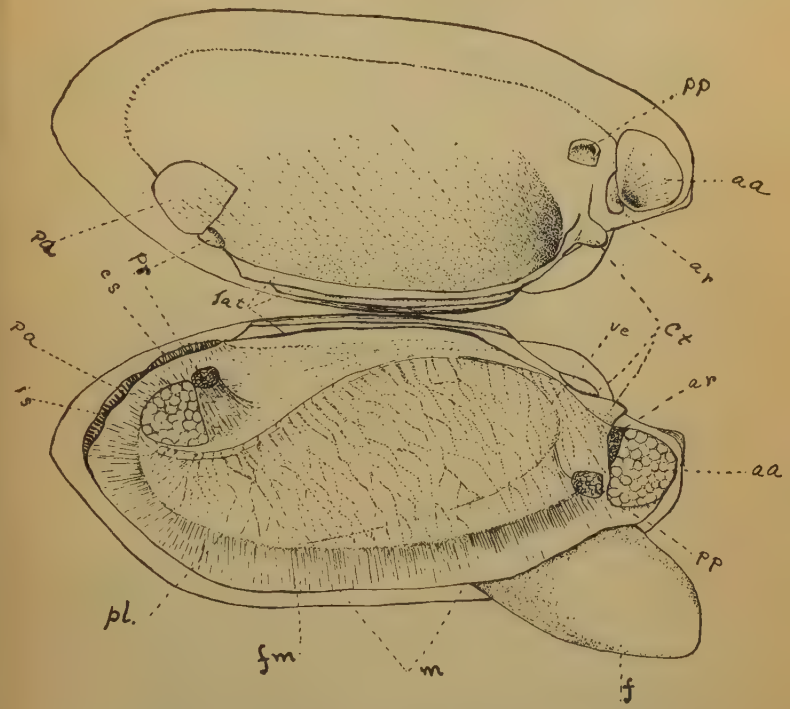


FIG. 98. — **Lampsilis luteolus**. Interior of shell and muscular system. *aa*, anterior adductor muscle and impression in shell; *ar*, anterior retractor muscle and impression; *pp*, protractor pedis muscle and impression; *pa*, posterior adductor muscle and impression; *pr*, posterior retractor muscle and impression; *f*, foot; *m*, mantle; *fm*, mantle fibers; *pl*, pallial line; *is*, inhalant siphon; *es*, exhalant siphon; *ve*, veins; *ct*, cardinal teeth; *lat*, lateral teeth. (From drawing by Miss Freda Detmers.)

are easily opened if the muscles are cut next one of the shells. The mantle incloses the entire body and extends to the margin of the shell, and posteriorly is modified into two siphons, the

branchial and **atrial** siphons, the former carrying an incurrent stream and the latter an outflowing current of water. Along the siphon margins in some forms may be seen dark pigment spots, and these evidently possess a slight visual property, as the clam will contract when a dark object passes over it. Within the mantle the more conspicuous parts are the foot, which may be protruded to a considerable distance beyond the shell margin;

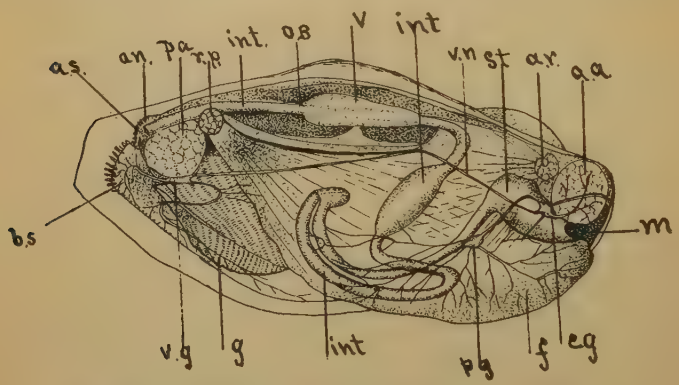


FIG. 99. — **Lampsilis luteolus**. Longitudinal section. *aa*, anterior, *pa*, posterior, adductor muscles; *pr*, posterior, *ar*, anterior, retractor muscles; *m*, mouth; *st*, stomach; *int*, intestine; *an*, anus; *c.g*, cerebral ganglion; *p.g*, pedal ganglion; *v.g*, visceral ganglion; *v*, ventricle; *OB*, organ of Bojanus; *g*, gills. (From drawing by Miss Freda Detmers.)

the gills, which are four broad leaf-like expansions, two on either side, containing the blood vessels for respiration; and the palps, two broad, thin appendages, lying just behind the mouth. The mouth opening is a simple aperture in the anterior portion of the body just under the retractor muscle, there being no head. It contains no radula, but extends by a simple esophagus back to the stomach, which is a rather large, capacious sac, into which ducts from the liver open. It then contracts sharply into a slender intestine which forms two or three coils in the body dorsal to the foot, and then passes backward, going through the ventricle, and terminating in an anal opening dorsal to the

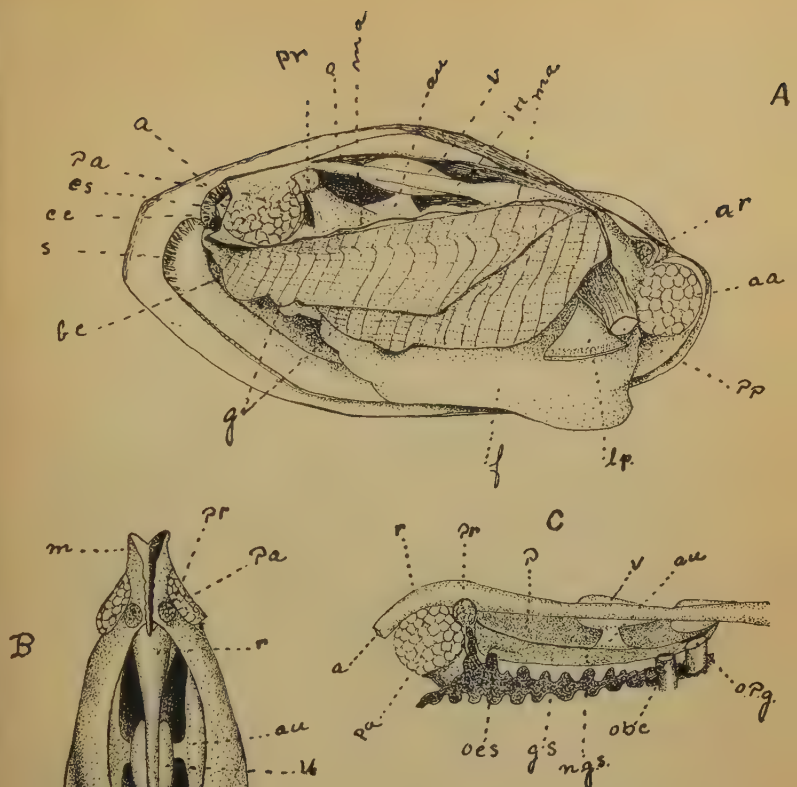


FIG. 100. — **Lampsilis luteolus.** A, view to show respiratory system. Mantle is cut off at upper margin of gills and still covers intestine and heart. *aa*, anterior adductor muscle; *ar*, anterior retractor muscle; *pp*, protractor pedes muscle; *lp*, labial palpi; *f*, foot; *g*, gills; *bc*, branchial chamber; *is*, inhalant siphon; *es*, exhalant siphon; *cc*, cloacal chamber; *pa*, posterior adductor muscle; *a*, anus; *pr*, posterior retractor; *ma*, mantle; *au*, auricle; *v*, ventricle; *in*, intestine, *p*, pericardium.

B, dorsal view of the pericardial cavity with mantle removed. *m*, mantle; *pr*, posterior retractor muscle; *pa*, posterior adductor; *r*, rectum; *au*, auricle; *v*, ventricle; *ob*, organ of Bojanus.

C, side view of pericardial cavity with organ of Bojanus dissected out. *a*, anus; *r*, rectum; *p*, pericardial cavity; *v*, ventricle; *au*, auricle; *pa*., posterior adductor; *pr*, posterior retractor; *oes*, opening of non-glandular into glandular portion of kidney; *gs*, glandular sac; *ngs*, non-glandular sac; *obc*, opening from non-glandular sac into branchial chamber; *opg*, opening leading from pericardium to glandular sac. (Drawings by Miss Freda Detmers.)

gills and within the atrial chamber. The food of the clam is carried in by the currents of water drawn over the gills to the mouth. It consists of minute aquatic organisms which are taken from the water by the cilia of the palps, and, on account of their minute size, require no such organ as the radula of the snail for their mastication. The liver mass surrounding the stomach is rather large, and opens by small ducts into the stomach cavity.

The blood system is somewhat complex, the dorsal heart con-

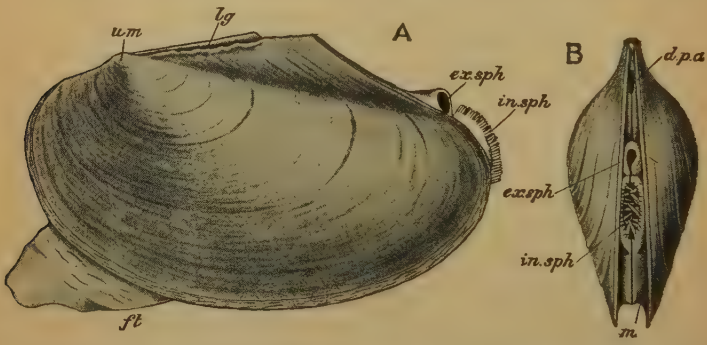


FIG. 101. — **Anodonta cygnea**. The entire animal. A, from the left side; B, from the posterior end. *d.p.a*, dorsal pallial aperture; *ex.sph*, exhalant siphon; *ft*, foot; *in.sph*, inhalant siphon; *lg*, ligament; *m*, mantle; *um*, umbo. (After Howes.)

sisting of a well-developed ventricle which surrounds the intestine and which gives off arteries both anteriorly and posteriorly that serve to distribute the blood to the different parts of the body. The blood collects in sinuses at the base of the gills and flows through the minute vessels of the gill plates for aeration, after part of it has passed through the kidney; also, it passes into pericardial chambers surrounding the heart, these merging into two distinct auricles which lie next to the ventricles and discharge the accumulation of blood through the valvular openings into the ventricle. The respiration is strictly aquatic, the broad leaf-like gills providing an ample area for the distribution of the

blood, and the currents of water drawn through the branchial siphon (see Fig. 98) pass over the gills and furnish a close contact between the water and the blood. In the return flow the

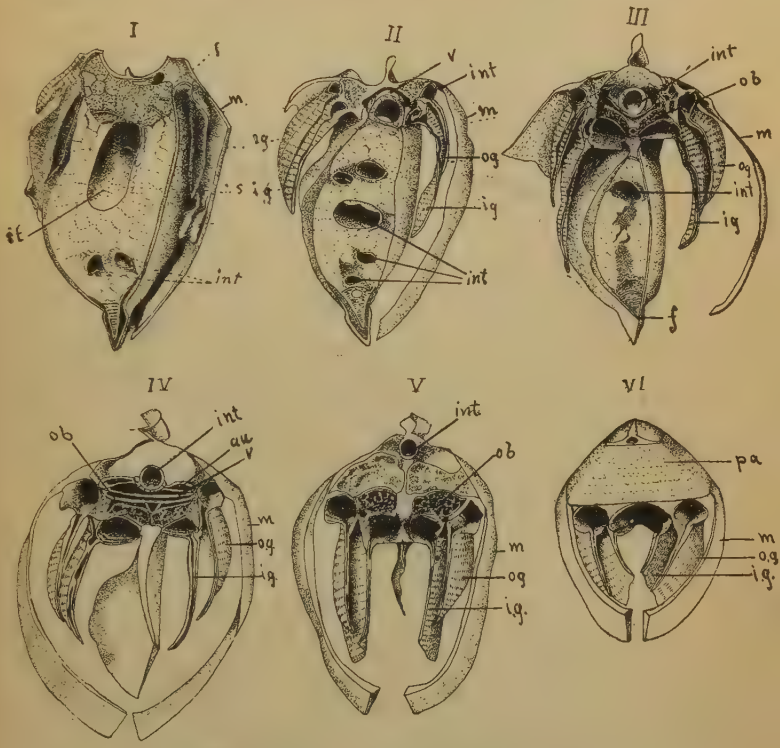


FIG. 102. — **Lampsilis luteolus.** Cross-sections at different points. *m*, mantle; *o.g*, outer gill; *i.g*, inner gill; *int*, intestine; *v*, ventricle; *au*, auricle, *ob*, organ of Bojanus; *pa*, posterior adductor muscle; *s*, stomach. (Drawing by Miss Freda Detmers.)

water current passes into and above the gill bases and through the atrial chamber, which is separated from the branchial chamber by a delicate membrane. The excretory organ consists of a distinct pair of nephridia which lie just beneath the auricles and consist of a quite distinct glandular and a non-glandular por-

tion, the former receiving a current of blood going to the gills, and the latter possessing a small duct opening into the atrial chamber at the anterior part of the gills. The nervous system consists of a pair of **cerebral** ganglia lying at the sides of the mouth connected by a commissure passing over the esophagus, a pair of **pedal** ganglia located within the foot and connected to the cere-

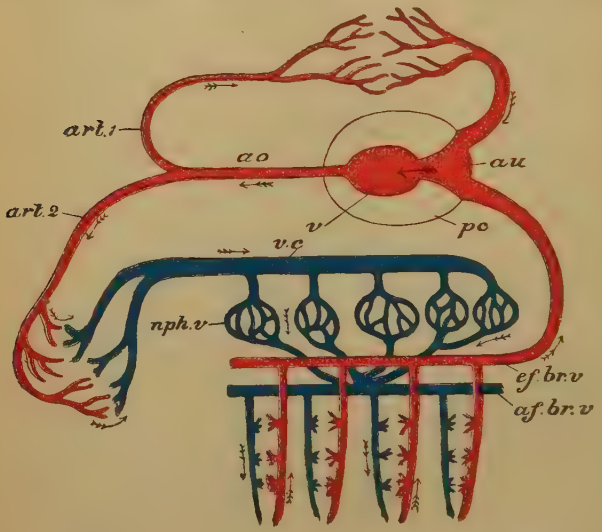


FIG. 103. — Diagram of the circulatory system of **Anodonta**. Vessels containing aerated blood red, non-aerated blue. *af.br.v*, afferent branchial veins; *ao*, aorta; *art. 1*, artery to mantle; *art. 2*, artery to body generally; *au*, auricle; *ef.br.v*, efferent branchial veins; *nph.v*, nephridial veins; *pc*, pericardium; *v*, ventricle; *v.c*, vena cava. The arrows show the direction of the current. (After Parker and Haswell.)

bral ganglia by nerve fibers on either side, and a pair of **visceral** ganglia located posteriorly under the posterior adductor muscle with nerve cords from the cerebral ganglia. The organs of sense are but poorly developed, vision, if present at all, being represented by pigment spots of the mantle margin, and the auditory organ is located within the foot. The olfactory organ or osphradium at the base of the gills may possibly have other function

also, while tactile areas are arranged on the mantle margin and the palps.

The sexes are distinct, the females usually showing a little difference in form of shell, and, at the time of breeding, the gills become distended with eggs and embryos. The ovaries are located in the dorsal portion of the foot, and the oviduct opens into the atrial chamber close to the opening of the nephridia. The testes are similarly located. Fertilization of eggs occurs in the atrial chamber by means of spermatozoa drawn in with the water currents, and the fertilized eggs accumulate in the atrial region and are crowded down into the middle space between the gill laminæ. There their development proceeds, the larva feeding upon a mucous secretion of the gill. After a certain amount of development in this stage the embryos escape from the adult clam and, for a number of our fresh-water species at least, attach themselves to fishes, anchoring themselves upon the tail fins or gills, where they become imbedded and pass through a temporary parasitic stage, called the Glochidium. Here a rather remarkable transformation occurs, during which the reduction of sensory organs takes place, and when the free stage is assumed, they take on the form of the adult clam.

The Oyster

The oyster is probably the most important of all of the mollusks commercially, and is also of great interest on account of its habits. It is distinctly adapted to sedentary life, not moving at all after having once fixed itself to some object at the bottom of the water. Oysters live mainly in muddy bottoms where there is a great abundance of floating forms of life, upon which they depend for their food.

The shell shows distinct adaptation to the fixed condition, the attachment being by one of the valves, the other permitting of free movement, so that water for respiration and food is readily drawn into the body. The shells become very rough as the

animal grows; it assumes a pear-shaped form, the hinge being at the small end. The foot is undeveloped, evidently from disuse. The single adductor muscle is toward the outer or larger end, and serves to bring the valves of the shell together when the animal is disturbed. The mantle margins extend slightly beyond the shell, and there is no distinct siphon, the water passing in near the margin and flowing over the gills which lie within the mantle, and along the ventral side of the animal. The mouth is located close to the hinge end and opens into the esophagus, which connects with a simple stomach lying about midway in the animal. Connected with this is a rather large liver which appears in the oyster as a large greenish mass, and which is in reality a considerable part of the nutritious portion of the animal. The heart is located close to the adductor muscle and forces the blood forward toward the head region and to other parts of the body. The blood collects as in other mollusks at the base of the gills, flows through the minute spaces in these, and is aerated by the water flowing through the gill chamber. The gills are of quite intricate construction, possessing a large number of minute tentacle-like foldings.

In their development oysters show an enormous ability for multiplication, a single oyster, it is estimated, producing as high as sixty million eggs, but a small portion of which, of course, can ever obtain conditions for development. The egg hatches into a minute, free-swimming organism, and this develops within a few days the rudiments of a shell, and in this stage, which is termed the "spat," settles upon some submerged object and becomes fixed, and from that time on grows into the form of the well-known adult stage.

Several points in this development are of special importance in the matter of cultivation of the species, since it is possible from the manner of egg laying and the early development to secure enormous numbers of young oysters in limited spaces and to provide objects for them to attach to, such as oyster shells, bits of tile, and hard objects of almost any kind, and later distribute

these over the bottom of shallow water; that is, plant them in suitable places for their further growth. In this way extensive areas may be made productive, provided the oysters are left long enough to attain proper size. In some places definite methods of culture on this plan are in use, and the oyster industry by these means very greatly extended. The common oyster of the Atlantic coast is distributed from Massachusetts to the Gulf, but has its best development, perhaps the best conditions for its growth, in the Chesapeake Bay, and this has been in the past one of the greatest centers of the oyster industry. It engages the attention of many thousands of individuals, and a large amount of capital is invested in boats, dredging appliances, and implements. About ten and a half million bushels were marketed in 1880, and it is said this amount has been about the limit in later years. These, at twenty cents per bushel to the fishermen, mean about two millions of dollars annually; but Professor Brooks estimates that this same area, if properly cultivated, that is, if the suitable shallow waters of the Chesapeake Bay were fully utilized, would produce at least sixty millions of dollars' worth of oysters annually. He also shows that the only reason why this greater development has not occurred lies in the fact that no suitable regulations are enforced for the propagation of oysters and protection of beds which might be planted by individuals or private enterprise.

These figures give some idea of the immense numbers involved in this industry, based on a single species of aquatic mollusk, but some further idea will be gained if we call to mind the immense numbers marketed in all the inland cities as well as those along the coast, and especially if we could see the immense masses of shells which are manufactured into lime or built into roads in the vicinity of Baltimore.

Definite methods of oyster farming are in force in Long Island Sound, on the Connecticut shores, in Rhode Island, and also in Virginia, North Carolina, and Louisiana, and in these states the industry is said to be rapidly growing. There are species of oysters used as food grown in the Mediterranean and on the Pacific

coast, but none of these reach the perfection or furnish the basis for so great an industry as the Atlantic coast species.

Marine clams of several species are used extensively as food, the most important being the *Mya arenaria* that is the usual foundation for the clam bake. The edible mussel, *Mytilus edulis*, a smaller species, is interesting on account of the development of the **byssus**, a growth of threads which serve to anchor the animal to rocks.

Another considerable industry is based on the pearls which form from the nacreous material secreted by the mantle. These grow by additions of extremely thin concentric layers around some nucleus, often a grain of sand or other particle of hard substance that has lodged between shell and mantle. The greater part of this industry is based on the pearl oyster, *Meleagrina margaratifera*, which flourishes in the shallow waters of the Indian Ocean and other marine waters, and is gathered by pearl divers. But pearls of excellent quality are often found in other species, and they occur frequently enough among our common fresh-water clams or "mussels" to furnish productive employment to a considerable number of people. Unfortunately there has been little or no care exercised in gathering the clams, and in many streams they have been practically exterminated. The same condition has resulted in some localities where button factories have been established to utilize the shells in manufacture of buttons, another important industry based on the quality of the nacreous layer of the

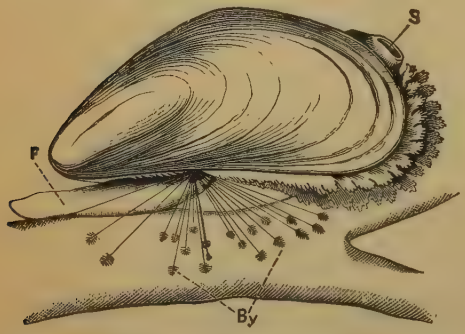


FIG. 104. — **Mytilus edulis**, attached by byssus (*By*) to a piece of wood. F, foot; S, exhalant siphon. (From the *Cambridge Natural History*.)

shell. The adoption of proper regulations to provide for the preservation or increase of clams would give such industries a permanence that would make them of great value.

A common and a very important species of mollusk is the ship worm (*Teredo navalis*). This is now distributed in all parts of the world where shipping reaches, and is especially destructive to piles and wharves and also to wooden vessels. The replacement by iron and steel of the wooden vessels has of course much reduced the danger to shipping, but its distribution is now so extended that its injuries are to be encountered practically everywhere that wharves or docks are built. It shows a very distinct departure from the ordinary habits of mollusks, but it is included in a group of boring species, some of which puncture rocks. In this species the burrows into wood may reach a depth of many inches, sometimes as much as two feet, and the animal is elongated to such an extent that while the head portion and remnant of shell is at the innermost part of the burrow, the posterior portion and the siphons through which it secures its supply of food by currents of water passing in and out are located at the surface of the timber. The food consists of microscopic organisms, as in other mollusks. It follows from this that growth is most

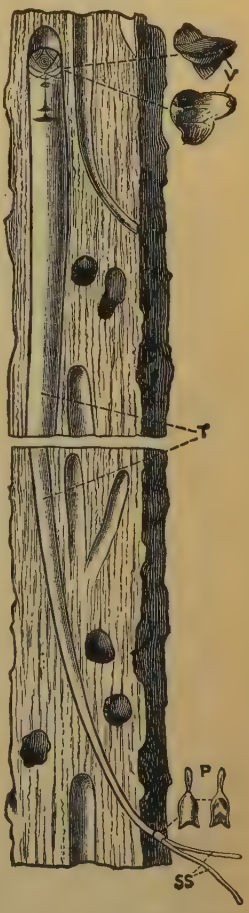


FIG. 105. — **Teredo navalis**, in a piece of timber. P, pallets; SS, siphons; T, tube; V, valve of shell. (From the *Cambridge Natural History*.)

rapid, and that ship worms are most liable to be destructive, in shallow waters of harbors where there is an abundance of microscopic organisms for their food supply. Although their borings are made entirely for the purpose of protection, and the wood is not eaten, the extent of the burrows and immense numbers which may occur cause serious havoc to structures made of wood. Heavy planks and timbers are completely riddled by them in a very short period. It is noted as a peculiar fact that while these burrows may be so numerous as to completely occupy the space within the timbers and so that they interlace in every direction in a very intricate manner, the tubes never puncture each other and there is always a thin partition between adjacent burrows. Protection against their injury is difficult and partial. The use of copper and iron sheathing for vessels has served to eliminate their danger, and in some cases piling is driven full of nails, the rust formed by the heads serving as a protection against the teredo. On the Atlantic coast the use of verdigris paint for spars and buoys is common; but this has to be replaced every six months, and in spite of this treatment the timbers will usually last but about twelve years, one half of which is spent out of the water. Species related to this occur in different parts of the world, but these are not so widely distributed or so injurious.

The species in the genus *Pholas*, which are related to Teredo, are remarkable for their ability to burrow into solid rock, but their burrows usually extend only deep enough so that the shell is included, and the siphons do not have to be greatly extended to reach the water. The shells of this form are extremely thin and delicate, which fact may be associated with the protection which they get within their rock burrows, but it is not so easy to understand how they are able to burrow out the cavities within which they live.

Class Cephalopoda

The Cephalopoda are a group of highly specialized moliusks, presenting a most extreme development of certain organs, and

retaining much more active habits than are common to the other groups.

The body is bilaterally symmetrical, but there is a large elevated visceral hump — the position of which in various swimming forms is such that the animal, apparently in a horizontal position, has the visceral hump directed backward. The arms or feet surround the mouth anteriorly. Except in nautilus, there is no external shell, but the body is included in a tough mantle in which on the dorsal portion is included usually a cuttle bone or a pen, which is the homolog of the shell. The head is prominent, and connected by the neck with the body, and bears two small eyes and a series of eight or ten strong arms containing a great number of sucking disks which serve to fasten the animals captured for food. Beneath the head is a tubular conical siphon through which water is forced. The current of water forced out in this manner provides a means of propulsion for the animal, enabling it to make sudden movements in a backward direction. It swims forward by means of lateral folds of the mantle. The flow of water in and out of the branchial cavity serves for respiration.

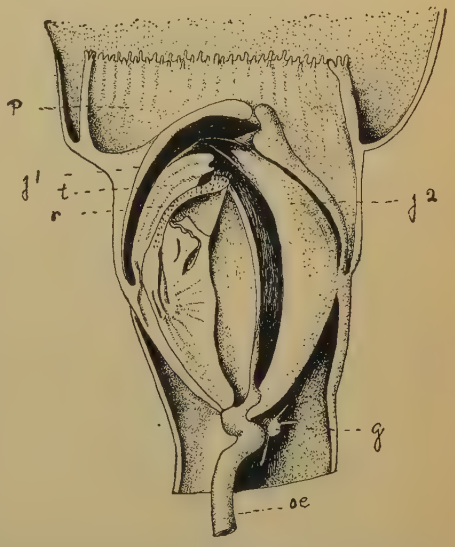


FIG. 106. — Buccal mass of **Ommastrephes**. *œ*, esophagus; *g*, buccal ganglion; j^1 and j^2, jaws; *p*, peristome; *r*, radula; *t*, taste organ. (Drawing by Miss Freda Detmers.)

The alimentary tract begins with a rounded mouth lying within

a circle of arms; this leads in to a capacious cavity which includes a large buccal mass, consisting of a strong, horny beak, and a well-developed tongue with a rasping radula. The esophagus is slender, but expands into a capacious stomach, connected with a large cæcum, and by a turn in the intestine the canal bends forward, the anus being near the base of the siphon. Lying upon the intestine is an ink sac, the contents of which are discharged through a duct near the anus, so that an inky fluid is discharged with a current of water through the siphon. This serves to form a black cloud, behind which the animal is hidden. This serves as a protection against enemies or as a shield to enable the animal to more easily capture its prey.

The vascular system consists of large ventricles from which the arteries drive the blood forward and backward through the various organs, and from the body the blood is collected in sinuses at the base of the gills. Here are located the branchial hearts, which serve to force the blood on into the gills, and from these the blood is collected and passes up the branchial veins to the auricles, which in turn pour the blood into the ventricle. The respiration is strictly aquatic — the gills located in the chamber being two in number in the squids (*Dibranchs*) and four in number for the nautilus and allied forms (*Tetrabrachs*).

The nephridia lie near the heart, the ducts opening anteriorly in the mantle chamber. The nervous system is quite specialized; the cerebral, pleural, and pedal ganglia being aggregated in a large nerve mass surrounding the esophagus and giving off numerous nerves to the arms; a large pair to the eyes and also fibers running to the stellate ganglia in the mantle margin. The eyes are remarkably well developed and strikingly like the vertebrate eye in mechanism, but totally different in origin and relation to the brain. In more specialized squids there is a distinct cornea perforated near the margin to admit water; a large crystalline lens, composed of a distinct anterior and posterior section, behind this a large vitreous humor, corresponding with the transparent vitreous humor of the vertebrate eye. In the retina rods and

cones are directed toward the pupil instead of from it, as in the vertebrate eye, showing a fundamental difference in the eye structure. In the simpler eye of the nautilus there is no crystalline

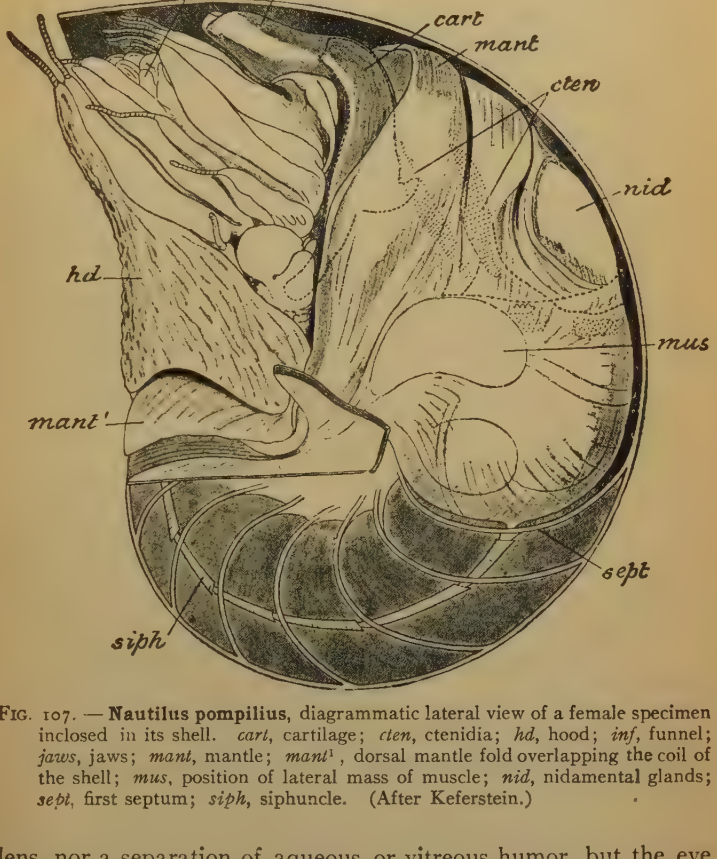


FIG. 107. — **Nautilus pompilius**, diagrammatic lateral view of a female specimen inclosed in its shell. *cart*, cartilage; *cten*, ctenidia; *hd*, hood; *inf*, funnel; *jaws*, jaws; *mant*, mantle; *mant*^{1}, dorsal mantle fold overlapping the coil of the shell; *mus*, position of lateral mass of muscle; *nid*, nidamental glands; *sept*, first septum; *siph*, siphuncle. (After Keferstein.)

lens, nor a separation of aqueous or vitreous humor, but the eye cavity opens to the exterior by a minute opening; light rays are thereby projected upon the retinal surface through the medium of sea water. The image so produced is on the principle of the

camera obscura, being less distinct than when the rays are concentrated by means of a crystalline lens. The structure of the eye in these different forms shows a gradual perfection of organism, and, moreover, presents a most striking parallelism to the structure of the eye in vertebrates. There is, of course, no possibility that the vertebrate eye could have been derived from the cephalo-

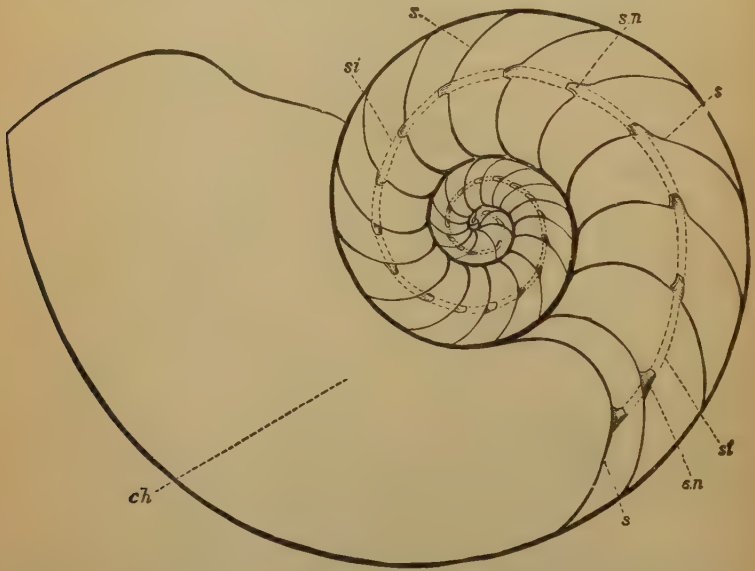


FIG. 108. — Section of the shell of **Nautilus pompilius**, showing the septa (*s*, *s*), the septal necks (*s.n*, *s.n.*), the siphuncle (*si*, represented by dotted lines), and the large body chamber (*ch*). (From the *Cambridge Natural History*.)

pod eye, and so the adoption of identical optical principles is of particular interest. The senses of hearing, tasting, and smelling are probably much less specialized.

The Cephalopoda are carnivorous, and in general very voracious animals, feeding upon crustacea, particularly small lobsters, fishes, and other aquatic animals, catching them by means of long sucker-bearing arms and grinding them with the powerful beak. They possess but little positive economic value, although in some

localities certain species of squid are used for food. Cuttlebone is extensively used as food for canaries, and formerly the inky secretion was extensively utilized under the name of India ink, or

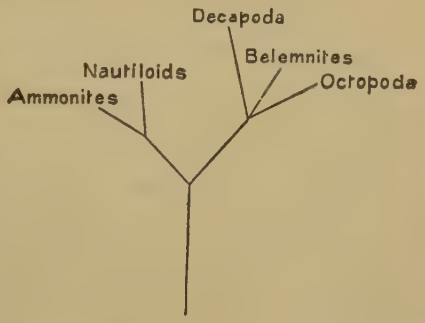


FIG. 109. — Diagram to illustrate the relationships of the groups of Cephalopoda. (After Parker and Haswell.)

sepia, for drawing and other purposes. Squid are used extensively for fish bait, particularly in the cod fisheries; and in some localities considerable numbers are collected and used on farms near the coast line as a fertilizer.

CHAPTER X

ARTHROPODA

The animals included in this general group, while possessing many features in common, have also certain marked differences which make it doubtful whether the group is to be considered a natural one, or, to put it broadly, whether all the classes included under it may have arisen from a single ancestral form.

We group here the crayfishes, lobsters, crabs, barnacles, centipedes, spiders, mites, and insects, and these groups include a very large proportion of the animal kingdom. There are more species of animals known in this division than in all the rest of the animal kingdom together, and inasmuch as new forms are constantly being discovered, the proportion is likely to increase.

We have here also some of our most important species that affect human interests, in forms furnishing important food products or other commercial materials, while great numbers have a most important relation to man in their destruction of property or as agents of disease.

The Arthropoda, if taken as a group, may be defined as including animals in which the body has a hard external skeleton provided with articulate segments and bearing segmented, or jointed, appendages. The external skeleton is composed most commonly of a substance termed chitin, which forms an extremely hard body covering, to the inner walls of which are attached the muscles which provide for the movements of the segments or appendages. In general location of the nervous system, in the character of the circulatory organs, and in some other features, the groups of the Arthropoda present similarities; but there are also quite definitely distinct types of structure in the different classes, and it is per-

haps preferable to treat each class more particularly by itself rather than take as a type of the Arthropoda any member of one of these classes. It may be remarked, however, that the most prominent line of separation is based on the functional differences in respiration. The aquatic gill-breathing forms constitute a class, Crustacea, while the other classes include air-breathing forms provided with tracheal or lung respiration.

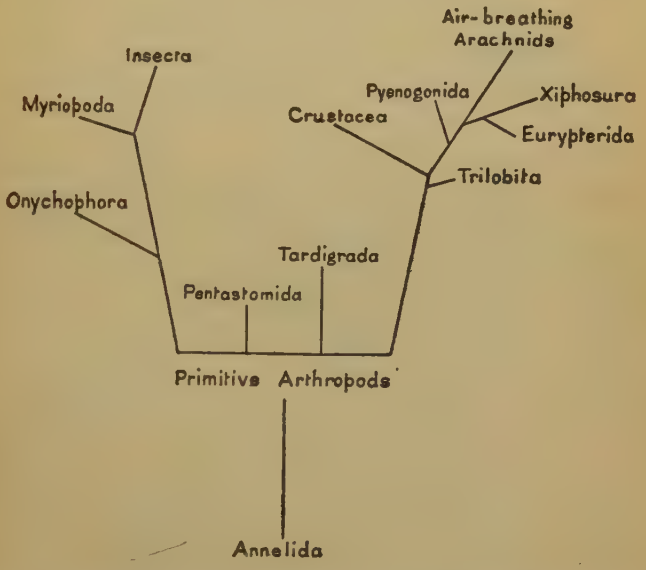


FIG. 110. — Diagram to show relationships of the different groups of the Arthropoda. (After Parker and Haswell.)

While difficult to determine the exact lines of derivation for the different groups, it seems probable that they arose from a common ancestral form which may have been related to a primitive form of annelid. Some suggestion of this is given in the diagram which presents the view adopted by Parker and Haswell in their text-book.

Class Crustacea

The Crustacea are aquatic in their method of respiration, being provided with gills, or branchiæ, and their normal habitat is aquatic, although certain specialized forms have become adapted to living out of the water, but always with some modification of the gills, so that they are kept moist, and consequently the respiration is similar to that of those forms living in water. Lobsters, crayfishes, and crabs are common and familiar forms, but on account of their wide distribution inland and their occurrence in all countries, the crayfish are the most convenient types for laboratory

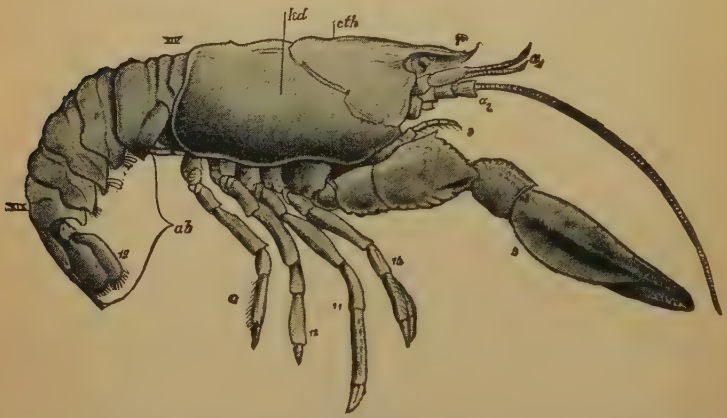


Fig. 111. — **Astacus fluviatilis**, side view of male. a_1, antennule; a_2, antenna; *ab*, abdomen; *cth*, cephalothorax; *kd*, gill cover; *r*, rostrum; *8*, third maxilliped; *9*, first leg; *10–13*, remaining legs; *19*, uropod; XIV, first abdominal segment; XIX, sixth abdominal segment. (From Lang's *Comparative Anatomy*.)

study. The more common forms belong to the two genera Astacus and Cambarus, and in general the features of the species are so similar that a description of one will apply quite well to the others; but it should always be remembered that in any comparison of minute details of structure these different species may show distinct differences. The species available in all of the

eastern and central portion of the United States belong to the genus Cambarus, and while there are several species likely to be taken, it is unnecessary, except for special comparison, to identify them.

Externally we may note the rigid body wall, the segments of the front part being fused into a compact structure, the cephalothorax, and the posterior portion, or abdomen, consisting of six freely movable segments bearing appendages, and a terminal segment, the telson. A typical segment of the body consists of the dorsal portion, the tergite, a lateral portion at each side, the pleurite, and a ventral portion, the sternite. These, in the adult form, are thoroughly fused together and, especially in the cephalothorax, their limits are much modified by the specialized body wall.

Appendages. — Theoretically each segment of the body may be assumed to have a pair of jointed appendages arising from the lateral portion between the sternite and pleurite. These have striking modifications in the different parts, adapting them for different functions, as for sensation in the head region, grasping and grinding food in the mouth region, walking in part of the thoracic region, for reproduction and swimming in the abdominal region. These different appendages, however, may be reduced to a common primitive type, represented most nearly by the swimmerets, the fundamental parts of which are the basal portion, protopodite, consisting of two segments, and two series of segments forming the endopodite and exopodite. By modification, enlargement, or reduction of segments, elongation or loss of endopodite or exopodite, this primitive form of appendage is modified into all the different forms represented on different regions of the body and adapted to different functions. Based on this derivation from a common type, we have what is known as serial homology for the appendages. The homologies represented in the different parts will appear more fully in the consideration of the various appendages. Beginning with the head, we note a pair of compound eyes borne on prominent stalks, and

a pair of antennulæ in which both the endopodite and exopodite are represented by slender and minutely jointed structures. The antennæ are long, reaching, when directed backwards, to the abdomen beyond the thorax and consisting of the protopodite

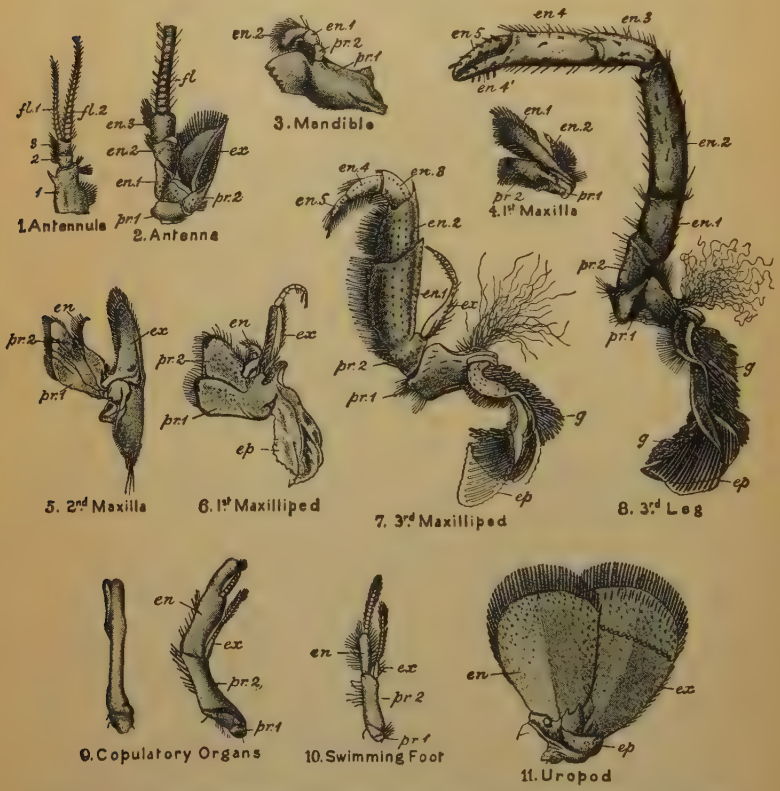


FIG. 112. — Typical appendages of **Astacus**. *en. 1–5* podomeres of endopodite; *ep*, epipodite; *ex*, exopodite; *fl*, flagella; *g*, gill; *pr. 1*, *pr. 2*, podomeres of protopodite; *1–3*, podomeres of axis of antennule. (After Huxley.)

and endopodite, the exopodite being represented by a small plate-like expansion. Next, a pair of mandibles developed as strong crushing organs and bearing a minute endopodite; two pairs of

maxillæ, the exopodites of which are somewhat modified; three pairs of maxillipeds, which are thoracic but associated with the mouth organs in function. The second maxilla bears a specialized exopodite, called the bailer or scaphognathite, which by vibrations in the gill chamber produces currents of water and thereby assists in respiration. The next five pairs of appendages, pereiopods, representing the thoracic region, have their principal function as locomotor organs in walking or creeping, but the front pair particularly is enlarged, the outer joints greatly developed and forming a strong pincer-like organ which is used both in capturing food and as an organ of defense. The pincer is formed by an elongation of the spur on the next to the last segment and against which the last segment is opposed. For explanation of the location and names of these particular segments the figures should be studied carefully. The first two abdominal appendages, or swimmerets, minute or

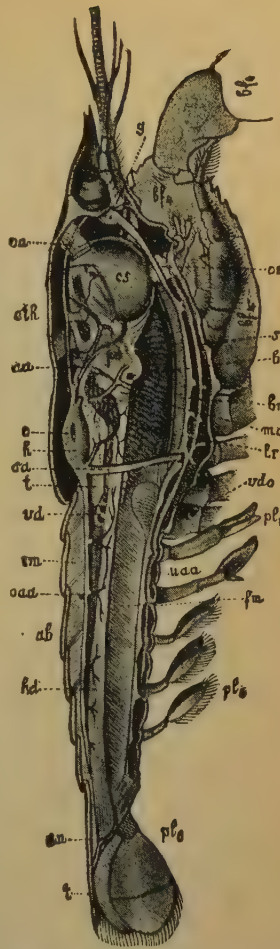


FIG. 113. — **Astacus fluviatilis**, dissection from the right side. *aa*, antennary artery; *ab*, abdomen; *an*, anus; *bd*, bile duct; *bf. 4*, cheliped; *bm*, ventral nerve cord; *cs*, cardiac division of stomach; *cth*, cephalothorax; *em*, dorsal muscles; *fm*, ventral muscles; *g*, brain; *h*, heart; *hd*, large intestine; *lr*, liver; *md*, small intestine; *o*, ostium; *oa*, ophthalmic artery; *oaa*, superior abdominal artery; *œ*, gullet; *pl. 1–5*, pleopods; *pl. 6*, uropod; *ps*, pyloric division of stomach; *sa*, sternal artery; *t*, testis and telson; *uaa*, inferior abdominal artery; *vd*, vas deferens; *vdo*, male genital aperture. (From Lang, after Huxley.)

absent in the female, are modified in the male to serve as channels for the sperm fluid, while on the sixth abdominal segment the exopodite is greatly expanded and forms the lateral portion of the broad tail fin.

Locomotion in the crayfish may be of two kinds, the creeping or walking movement based upon the movements of the pereiopods, and the action of the swimmerets which serve slightly to carry the animal forward through the water; the most important movement, however, results from a sudden doubling of the abdomen so that the broad tail fin strikes the water and throws the animal with a sudden jerk in a backward direction.

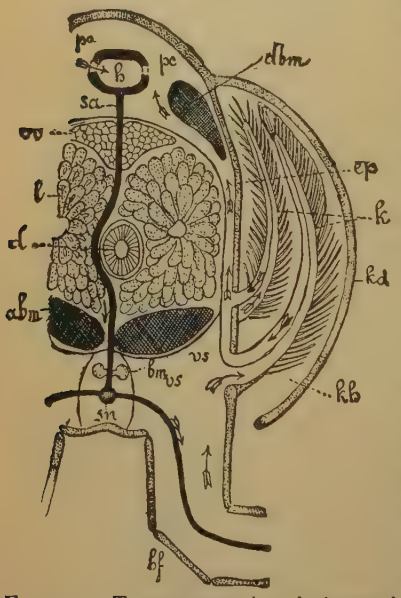


FIG. 114. — Transverse section of thorax of crayfish, diagrammatic. *abm*, ventral abdominal muscles; *bf*, leg; *bm*, ventral nerve cord; *d*, intestine; *dbm*, dorsal muscles of abdomen; *ep*, wall of thorax; *h*, heart; *k*, gills; *kd*, gill cover; *l*, liver; *ov*, ovary; *pc*, pericardial sinus; *sa*, *sn*, sternal artery; *vs*, ventral sinus. The arrow shows the direction of the blood current. (From Lang's *Comparative Anatomy*.)

The alimentary canal of the crayfish is of the usual arthropod type, but shows a rather remarkable development of grinding parts in the stomach, the gastric mill, composed of strong chitinous bars with muscular attachments providing for a grinding movement. This portion of the stomach belongs with the mouth parts to the portion of the invaginated ectoderm included in the stomodeum. A short central portion of the canal, the midgut, represents the primitive archenteron, while the intestine and rectum are lined with ectoderm and termed the proctodeum. The diges-

tive glands are connected with the midgut, and it is in this portion that the digestive process proper takes place. The intestine is slender and straight, terminating at the base of the telson in a slit-like anus.

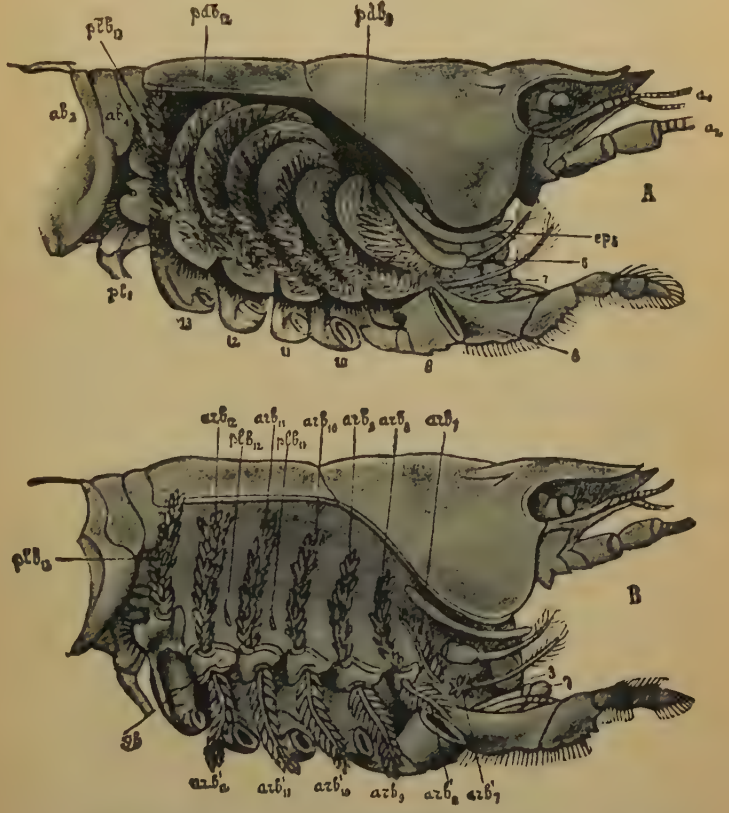


FIG. 115. — Respiratory organs of **Astacus fluviatilis**. In A the gill cover is removed and the gills undisturbed; in B the podobranchiæ are removed and the outer arthrobranchiæ turned down. a_1, antennule; a_2, antenna; ab_1, first; ab_2, second abdominal segment; *arb. 7–12*, inner arthrobranchiæ; *arb'. 7–12*, outer arthrobranchiæ; *epb. 5*, scaphognathite; *plb. 11–13*, pleurobranchiæ; *pdb. 7–13*, podobranchs; *pl. 1*, first pleopod; *6–13*, thoracic appendages. (From Lang's *Comparative Anatomy*, after Huxley.)

The circulatory system is rather complex, consisting of a dorsal blood vessel in the central thoracic portion of which is a large pulsatile sac or ventricle from which vessels run forward and backward, the blood being admitted to the ventricle through narrow ostia at each side. The blood driven forward and backward gathers in the ventral sinus, from which it is carried by lateral vessels into the branchiæ, where respiration occurs. There is also a sternal artery passing from heart to floor of thorax. From the gills the blood flows by a series of vessels or sinuses dorsally to the pericardial chamber from which it enters the heart.

FIG. 116. — Nervous system of **Astacus fluviatilis**. *bg*, subesophageal ganglion; *cs*, commissural ganglion; *g*, brain; *s*, visceral nerve; *sc*, esophageal connective; *y*, post-esophageal commissure; IV–VIII, thoracic ganglia; *1–6*, abdominal ganglia. (From Lang's *Comparative Anatomy*, after Vogt and Yung.)

Respiration in the crayfish is provided for by a series of gills or branchiæ located in a gill chamber at the sides of the body and inclosed by folds of the carapace so that they appear to be within the body wall. The transverse section (Fig. 114), however, will show that this chamber is strictly external to the body wall proper, and being open it freely admits water which flows in a current over the gills. Movement of the water is facilitated by vibrations of the baler or scaphognathite of the second maxilla. The gills in this chamber are located to correspond with seven pairs of appendages, three gills to each appendage, except for the anterior part, where they vary, thus making nearly twenty in all. Their attachment is to wall of the body, to the articular membrane between body and appendages, and on basal joint of the appendage, and these locations give rise to three names, **pleuro-**, **arthro-**, and **podobranchia**. They consist of feathery filamentous

bodies of extremely delicate tissue, and permit ready exchange of oxygen and carbon dioxide between the water and blood.

The nervous system forms a ventral chain with large ganglia brain above the esophagus, and a mass, the subesophageal, below, with five thoracic and six abdominal ganglia. See Fig. 116.

Excretion in the crayfish is provided for by the special excretory gland, termed the green gland, which lies in the anterior part of

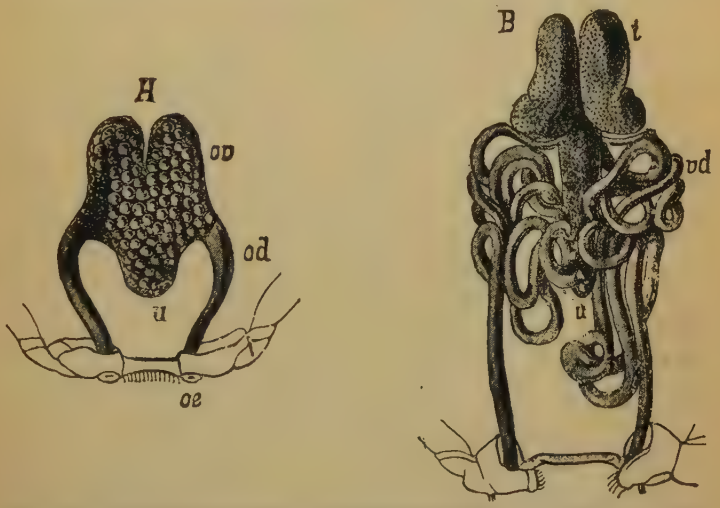


FIG. 117. — Reproductive organs of **Astacus fluviatilis**. A, female; B, male; *od*, oviduct; *oe*, external opening of the same; *ov*, ovary; *t*, testis; *u*, unpaired posterior portion of gonad; *vd*, vas deferens. (From Lang's *Comparative Anatomy*, after Huxley.)

the body behind the base of the antenna, and its duct opens on the basal joint of the antenna. These organs, if homologous with nephridia of annelids, show little similarity to them. The organ consists of a dorsal sac and a coiled tube, which is the functional part of the organ, and is surrounded by blood vessels from which are excreted uric acid and guanin.

The reproductive system in the crayfish occupies the dorsal central portion of the thorax, testes and ovaries lying in about

the same position, but the ducts leading from them open externally at different points, those of the female terminating in the second posterior pair of pereiopods, while the vas deferens opens in the posterior one. Eggs are extruded and held by a glutinous secretion on the under surface of the abdomen, where they are fertilized by spermatozoa previously deposited by the male. After fertilization, the eggs develop, remaining attached to the abdomen of the female. Development within the egg carries the embryo to an advanced stage, and the young crayfish when hatched has the essential form of the adult. In this respect it shows a quite striking difference from the more strictly aquatic crabs, which have a very distinct metamorphosis.

Crayfish abound particularly in streams and low land where the soil is limy. They live much of the time in open water, but often will be found in burrows, where they readily bore down to water level. These burrows often may be seen in swampy places, the opening of the burrow being surrounded by a little ridge of excavated earth. On account of their burrowing habit they sometimes cause serious trouble in dams and levees, the burrows furnishing opening for leakage of water and giving rise to extensive breaks. They feed on a variety of aquatic organisms and are themselves eaten by other carnivorous aquatic forms, and in some localities are considered a desirable table food. There is no reason why they should not be as palatable as shrimps, prawns, or lobsters.

Classification. — The Crustacea are divided into two main subclasses, Entomostraca and Malacostraca, the former including those which are mostly minute or in which the number of segments is quite indefinite, varying in different subdivisions from a few segments up to as high as fifty or sixty. The latter include mostly larger forms and have quite definitely twenty-one segments as the typical number. Among these are the more familiar crayfishes, lobsters, and crabs. In our review of the groups, it will be necessary to summarize especially the Entomostraca, where there are many orders and families, including a large number of genera and species.

Subclass Entomostraca

The members of this group are smaller and represent doubtless the more primitive forms of the crustacean class. In most cases they are of small size, but a few of them reach a length of an inch or two; and the barnacles, which are now included in this division, are sometimes, including the stalk, four or five inches long. The number of segments is quite indefinite, and the larva is hatched as a small unsegmented form termed the nauplius. No gastric mill is present, and except in the barnacles and the parasitic forms they are usually free swimming, and many of them constitute a large factor in the plankton of both salt and fresh water.

Order 1. Phyllopoda. — These are usually small, with a considerable number of segments, ten to twenty or more in Branchiopoda, few or indistinct in Cladocera. They are frequently protected by a bivalve shell, or carapace, inclosing most of the body. The last four pairs of swimmerets have broad respiratory plates. In this division we have the large "fairy shrimp," *Branchipus*, which is found in early spring in shallow pools of fresh water, but which is unknown at other periods of the year. The *Artemia* are brine shrimps which occur in salt and brackish water, and which have become quite familiar to biological students on account of the experiments in changing their habitat from salt to fresh water. Gradual change in the salinity of the water is accompanied by a change in the organism until the salt-water form assumes the character of the fresh-water species, and a reverse process transforms the fresh-water form to the salt-water species. One species, *Artemia fertilis*, occurs in Salt Lake, which on account of its extreme saltness contains very few forms of animals. The species of Daphnia frequently swarm in small bodies of fresh water, and with other species form a most important food supply for fishes.

Order 2. Ostracoda. — These are smaller forms, usually much compressed, the body indistinctly segmented or without apparent segmentation, the abdomen reduced or rudimentary, and the body

included within a distinct bivalve-like shell, appendages seven in number. These occur both as fresh-water and marine forms, and the genus *Cypris* includes a great variety of species which abound in lakes, ponds, and swamps, often constituting a large factor in plankton.

Order 3. Copepoda. — These have the body elongated and distinctly segmented except in the extreme parasitic forms. There is no bivalve shell, but the anterior segments are often combined into a distinct carapace. The appendages are confined to the head and thorax, and in most forms there is a single median eye. The egg sacs are usually external, extending from the posterior angles of the thorax. A great many forms occur as active independent organisms, often constituting an enormous proportion of the content of aquatic life, but many others have become adapted to parasitic habit and are to be found attached to the gills or within the mouth cavity of fishes, and showing all stages of degeneration as a result of this parasitic habit. In some cases this degeneration has gone so far that in the adult there is practically nothing but a root-like attached portion bearing enormous egg sacs which hang freely in the gill cavities. In all forms, however, the eggs hatch into a free-swimming nauplius stage, and these forms must swim about and take their chances of coming into contact with the gills of the fish, in some species apparently a particular kind of fish, in order that they may continue their growth and provide for the perpetuation of their species. Doubtless, enormous numbers of them never succeed in finding the proper host, but to compensate for this the number of eggs produced by those which do succeed in attaching themselves is greatly multiplied. While the host fishes supporting these parasites may not show very marked injury, there can be little doubt that when they occur in any considerable number they must sap the vitality of the fish, interfere with its normal functions, especially in the proper aeration of the blood which flows through the gills, and in this way have a distinct importance in relation to the fish industries.

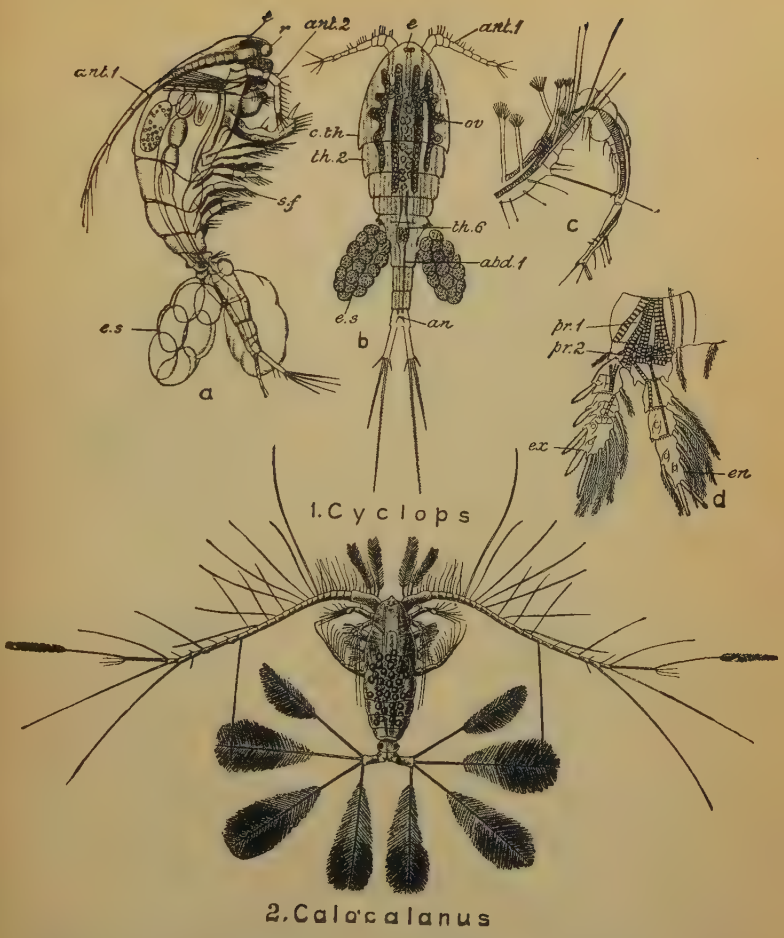


FIG. 118. — *1a*, female **Cyclops**, from the right side; *b*, dorsal view; C, antenna of male; D, swimming foot. *abd. 1*, first abdominal segment; *ant. 1*, antennule; *ant. 2*, antenna; *c.th*, cephalothorax; *e*, median eye; *en*, endopodite; *e.s*, egg sac; *ex*, exopodite; *ov*, ovary; *pr. 1*, *pr. 2*, protopodite; *r*, rostrum; *s.f*, swimming feet; *th. 2*, *th. 6*, thoracic segments. (After Huxley, Gerstaecker, Hartog, and Giesbrecht.)

Order 4. Cirripedia. — This order includes the goose barnacles, acorn barnacles, and some degenerate parasitic species. The most striking feature of the group is shown in the attached condition and the development of calcareous plates or fleshy stalk for attachment. The species are all marine, and while they have a short free-swimming nauplius stage, they attach themselves,

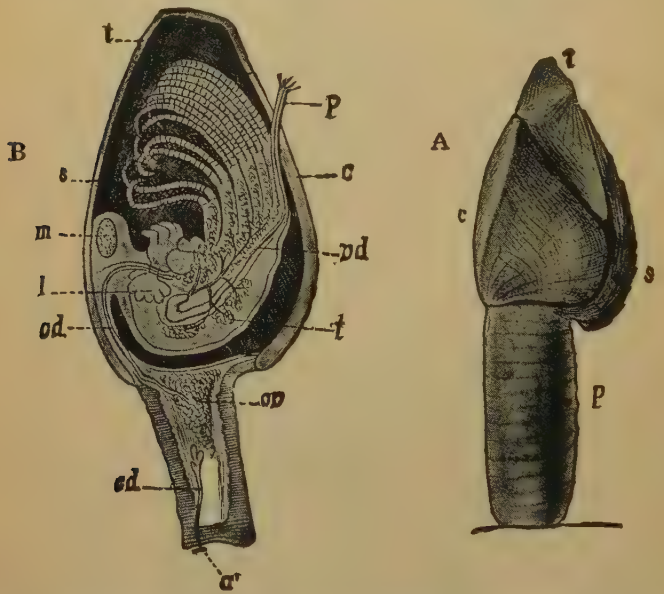


FIG. 119. — **Lepas anatifera**. A, the entire animal; B, its anatomy. a^1, antennule; *c*, carina; *cd*, cement gland; *l*, digestive gland; *m*, adductor muscle; *od*, oviduct; *ov*, ovary; *p*, (in B) penis and (in A) peduncle; *s*, scutum; *t*, tergum and testis; *vd*, vas deferens. (From Lang's *Comparative Anatomy*, after Darwin and Claus.)

head downward, upon various objects, — floating timbers, surface of ships, rocks, etc., — after which they remain fixed and their development is adapted entirely to their sedentary condition. The first antennæ are modified for attachment, the second pair rudimentary, the mouth parts small, more or less reduced; but there are a series of biramous thoracic feet

(cirri), which by rapid vibration draw currents of water and food particles within the valves of the shell and into the mouth. The abdomen is much reduced, the heart wanting, the sexes often combined, but in many cases where the sexes are distinct the males occur as minute parasitic individuals attached to the females.

A quite remarkable condition is shown by the parasitic genus **Sacculina**, which occurs upon the under side of the abdomen of crabs. It is considered as the most degenerate of all parasites, consisting only of an ovoid sac, on the lower surface of which there is an aperture opening into a brood chamber usually distended with eggs. The attaching stalk extends within the body of the crab and there breaks up into numerous branches or roots which ramify through the body and provide for the supply of nutrition upon which the eggs may be developed. It is said to live for a period of three years, during which time the parasitized crab is so much affected that its growth is arrested and moulting stopped.

Subclass Malacostraca

These are larger and more specialized forms, the body segments being quite constant in number, five of which may be referred to the head region, eight to the thorax, and seven to the abdomen. Appendages are found on each of these segments except the terminal one, but show very great diversity in adaptation to different functions. The segments of head and thorax are usually closely connected, termed together the cephalothorax, and frequently inclosed in the carapace. The eyes are paired, compound, often on stalks; the stomach includes a gastric mill; and the development usually goes beyond the nauplius stage before hatching. In some forms a striking metamorphosis occurs, but in others development is direct after hatching.

I. Leptostraca.—This group includes a small number of forms, all marine, of rather simple structure and distinctly intermediate between the Entomostraca and other groups of Malacostraca. They differ from other divisions in having eight abdominal seg-

ments instead of seven, and the body is inclosed within a delicate bivalve shell.

II. Arthrostraca. — In these we have the abdomen with seven segments, the first thoracic segment and sometimes the second fused with the head, but other thoracic segments free. The abdominal appendages are modified to form respiratory organs, the first pair forming a plate-like covering, the others developed as gills.

Order 1. Isopoda. — These are flattened or semicylindrical forms, in many cases adapted to doubling up so as to form a ball, as in the case of the familiar pill bugs; a considerable number are terrestrial, others live in fresh water, and perhaps the larger portion in salt water. A few occur attached to the gills or in the mouth of fishes in a semiparasitic condition. Our common sow bugs and pill bugs are found frequently and sometimes in large numbers under boards, bark, or stones or around cisterns or in cellars, where they find the necessary amount of moisture.

A quite remarkable and destructive species is the little *Limnoria*, which burrows into submerged timber in salt water, attacking particularly such structures as piles and wharves; and in this respect the species is a distinct departure in habit from most of the Isopods, and shows the possibility of different members of the group adapting themselves to very different modes of life. In its injuries to wooden structures it ranks close to the shipworm (*Teredo*), which has been mentioned among the mollusks. The treatment of this species is somewhat different, however, since it feeds upon the woody fibers and may be poisoned or its attacks prevented by soaking the timber in some poisonous or repellent solution. The solution which is most commonly used for this purpose, perhaps, is creosote, and the process of saturating the wood with this substance is called **kyanizing**.

Order 2. Amphipoda. — These differ from the Isopods most evidently in having compressed bodies. Many species are marine, some occur in fresh water, and some may survive temporarily on land as in the case of beach fleas or sand fleas. Certain forms show very marked adaptations to particular conditions, some are

parasitic, but few of them are of especial economic importance except as they constitute food for fishes or other aquatic animals.

III. Thoracostraca. — These are the largest and most notable of the Crustacea, including among others the crayfish, lobster, shrimp, etc. The thoracic segments are fused with the head, and the eyes are borne on distinct stalks.

Order 1. Cumacea. — This group is most nearly intermediate between the simpler orders and typical higher forms, the eyes not being stalked and the carapace covering part of the thoracic segments. All are marine and of slight importance compared with other forms.

FIG. 120. — Fresh-water shrimp, **Palæmonetes**, with eggs. (From drawing by D. D. Shira.)

Order 2. Stomatopoda. — In this group we have a very peculiar form, the mantis crab, *Squilla*, which in general appears strikingly like and suggests the praying mantis among insects. The abdomen is much widened behind, and it is attached to the thorax by a rather slender base. The anterior pair of the thoracic appendages are much enlarged and adapted for grasping.

Order 3. Schizopoda. — This is a small division including strictly marine forms, muscular, delicate, transparent creatures

with rather simple biramous appendages, the thorax included in a delicate carapace, and the sixth abdominal segment provided with elongated appendages, forming with the seventh segment a rather strong tail fin. The genus *Mysis* includes the common forms.

Order 4. Decapoda. — These are the largest of the Crustacea, some of the species reaching the length of two feet or more and an

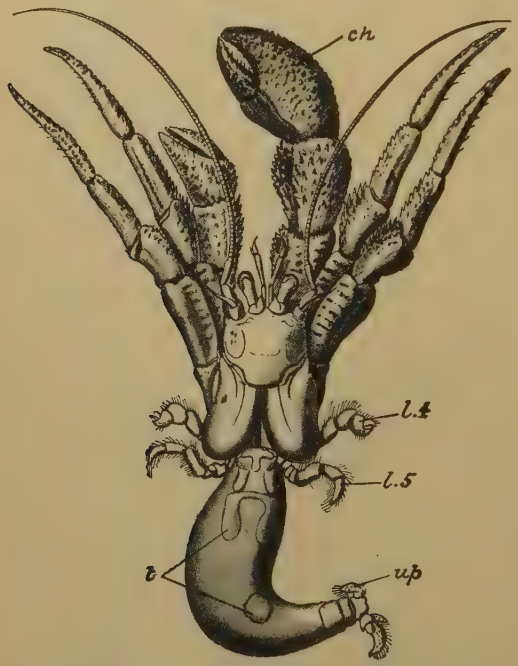


FIG. 121. — **Pagurus bernhardus.** *ch*, chela of first right leg; *l. 4*, *l. 5*, fourth and fifth legs; *t*, abdominal terga; *up*, uropods. (After Bell.)

expanse of appendages of six or seven feet. They are characterized especially by the large stalked compound eyes, the marked separation between cephalothorax and abdomen. The crayfish, already described in detail, will stand as a typical example of the group.

It is separated into two suborders, on the character of the abdomen: Macrura, including those which, like the crayfish and lobster, have the abdomen large and extended backward from the thorax, and the Brachyura, in which the abdomen is doubled under the thorax, much reduced in size, and sometimes fitting into a groove in the thorax, the abdominal appendages being very much aborted or lost. Among the Macrura the lobster, crayfishes, shrimps, and prawns are familiar common examples, on account of their abundance, wide distribution, and their use as food. The hermit crab is remarkable on account of its adaptation to living in the shells of marine snails, the abdomen becoming soft, the appendages reduced, the form adjusted to the spiral shape of the shell, while the anterior part of the body retains the hard characteristics of other forms. At different stages of its growth the crab must occupy different sizes of shells, and its exchange from a smaller to a larger shell is accompanied by danger on account of exposure of the soft abdomen, since this is a tempting bait for fishes. It is said that the transfer is made with great rapidity, the crab having found a shell of suitable size before attempting to shift from one to the other. Among the Brachyura we have a very large number of marine crabs, many of which are edible, while many show most striking adaptations to their surroundings, presenting remarkable cases of protective resemblance.

Relations to Other Animals

The Crustacea as a whole occupy a very important place in aquatic life, but a less important place amongst land forms, land crustaceans being evidently rather extreme adaptations from aquatic types. The smaller forms occur in immense numbers, and, being rather deficient in locomotion, serve as important food supply for other groups of aquatic animals, especially fishes and whales. The barnacles, by their attachment to bottoms of vessels, become a very serious interference to the progress of ships. So rapidly do they grow that, in tropical waters especially, it becomes necessary

to scrape the bottoms of vessels at frequent intervals, a process that is expensive both in labor and time.

Among the larger forms, which are mainly carnivorous, the relation to other forms of aquatic life is in the reverse order, since they prey more extensively upon weaker forms of animals and are themselves better protected against their enemies. They constitute a quite important factor in food supply for man also. Some of the forms, like the lobster, shrimp, prawns, and edible crabs, are used very extensively and constitute an important commercial product found regularly in the markets of different countries. So much in demand are the lobsters that their numbers on the Atlantic coast have been greatly depleted in recent years, and much concern has been felt lest the species should be so nearly exterminated that it could no longer be available for ordinary use. The annual consumption of this species, according to recent estimates, is something like 15,000,000, but the catch has been lessening at a rapid rate. Within the last few years much effort has been made to discover methods of increasing their numbers by rearing them from eggs, protecting their breeding grounds, and especially protecting them during the breeding season so that the species may be kept in abundant numbers for the future. The shrimps and crabs are likewise much used, but as yet no serious inroad upon their number seems to have occurred. The use of crayfishes as food is common to some localities, but perhaps not widespread, though their abundance and the fact that they may at times be caught in large numbers would seem to make it possible that they could be used quite extensively in the same manner as the shrimps are used.

Metamorphosis

The development of Crustacea presents many striking features and is especially significant as indicating the lines of evolution in the different orders. In most forms, as in the Arthropoda generally, there is superficial cleavage of the ovum; but in some of the more primitive species this is not well marked, and gradations from

simple total cleavage to the extreme forms of superficial cleavage may be traced. The most primitive larval form is the nauplius, an unsegmented creature, with usually three pairs of appendages, that swims readily and at a later period changes to the more complex form. Such a form occurs in the Entomostraca and also in the most primitive of the Malacostraca, as in the prawns. In most Malacostraca, however, hatching does not occur until after the

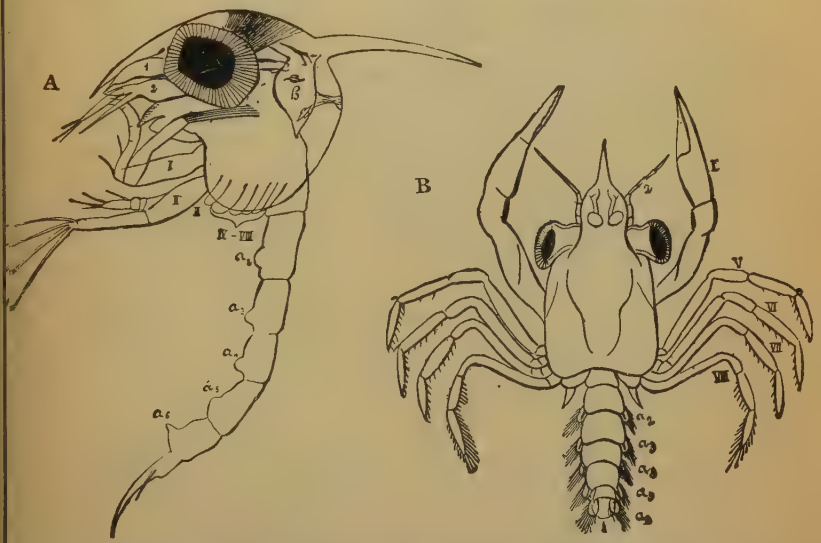


FIG. 122. — Larvæ of crabs. A, Zoæa stage of **Maja**; B, Megalopa stage of **Portunas**. *h*, heart; a_2–a_6, abdominal segments; *1*, antennule; *2*, antenna; I–VIII, thoracic appendages. (After Claus.)

nauplius stage has passed, and in some cases, as in the crayfish, the earlier steps of development are passed within the egg, and hatching occurs in the form of the adult, further development being direct. Within the Malacostraca, however, we find almost every gradation between the most primitive larval form and the most specialized ones in metamorphosis. In the crab, for instance, hatching occurs in a very simple stage, which may be compared

with one of the Entomostraca, the so-called "zoæa" stage, which is free-swimming and in which the abdomen is prominent. This changes to a more advanced form, the megalopa state, in which the eyes are stalked, the abdomen prominent, provided with swimmerets, and the general character not unlike the crayfish or lobster. From this stage, by further modification, especially by the broadening of the cephalothorax, the shortening and doubling

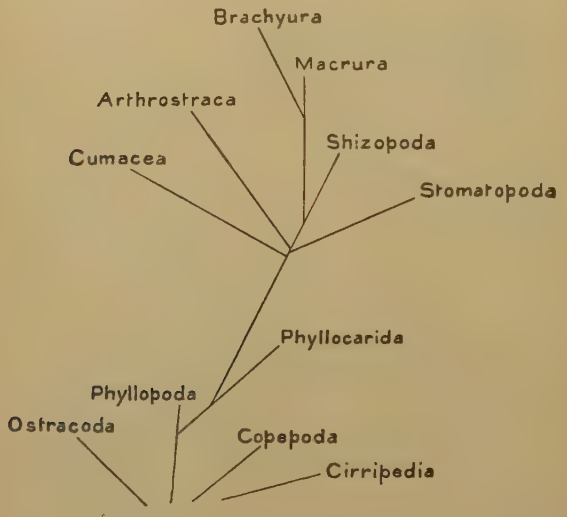


FIG. 123. — Diagram showing the mutual relationships of the orders of Crustacea. (After Parker and Haswell.)

under of the abdomen, the adult form is assumed. Comparing larval stages of species showing this kind of metamorphosis with the species that may be arranged in a morphological manner, we have striking similarities; and the conclusion seems warranted that these metamorphoses in the life of an individual crab are indications of the line of evolution for the species, the successive steps represented in metamorphosis corresponding in a general way with more primitive forms of earlier time.

Class Palæostraca

This group has been adopted to include certain divisions of Arthropoda which, while departing widely from the typical groups, possess certain fundamental characters which makes it necessary to associate them with the other classes of Arthropoda. While resembling Crustacea in some respects, there are other characters in which they seem more nearly related to the Arachnida, and we may for convenience place them between these two divisions. Perhaps the best view that can be taken of them at the present time is that they represent early offshoots, possibly independent branches, from a very early and primitive form of Arthropoda. If related to Crustacea, they have departed from them in the reduction or loss of antennæ, while if related to Arachnida, they show a much more primitive condition of respiration. The three orders agree in being aquatic and in character of eyes and in body regions. Two of them are entirely extinct, the other represented by a single surviving species. We may best consider each group by itself.

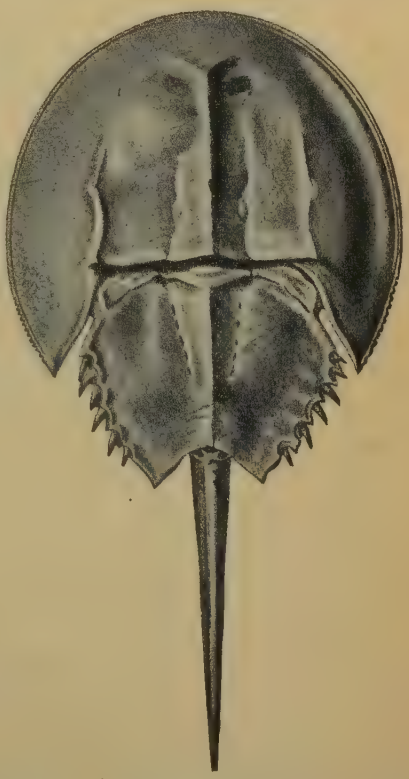


Fig. 124. — **Limulus.** Dorsal view. (After Leuckart.)

Order Xiphosura. — This order includes the king crab or horseshoe crab, a very common animal along the Atlantic coast, from Maine to the Gulf, and which also occurs in the West Indies and in the western part of the Pacific Ocean on the shores of the Molucca Islands.

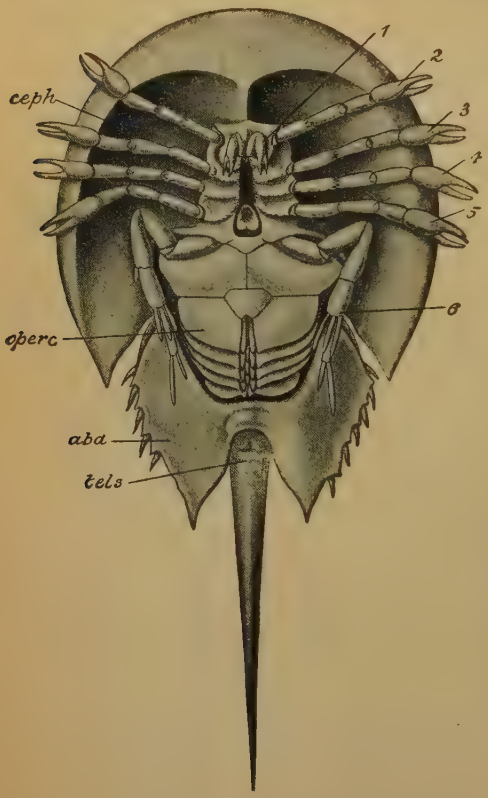


FIG. 125. — Ventral view of **Limulus**. *1–6*, appendages of cephalothorax; *abd*, abdomen; *ceph*, cephalothorax; *operc*, operculum, behind which are seen the series of abdominal appendages; *tels*, caudal spine or telson. (From Packard, after Kingsley.)

The cephalothorax is large, distinctly vaulted, almost circular, extending posteriorly into two sharp angles, and the posterior border cut out to receive the abdomen. The abdomen consists of several segments fused dorsally and bearing posteriorly a long spine or telson. Underneath, within the vaulted space, there are six pairs of appendages for the thoracic region and five pairs of respiratory plates on the abdomen, covered in front by a broad operculum.

The mouth opening is near the center, between the bases of the

thoracic appendages, the esophagus extending forward and enlarging into a broad stomach in the dorsal portion of the cephalothorax. A valvular opening leads to the midgut, and this merges into the intestine, which terminates at the base of the telson. The heart is large, the main contractile vessel lying in the dorsal region within a pericardium and possessing eight ostia which open into eight chambers, the contraction of which forces the blood forward. A rather complex series of arteries leading from this dorsal heart are distributed over the body and are peculiar in that they surround the principal nerve cords in the ventral part of the body.

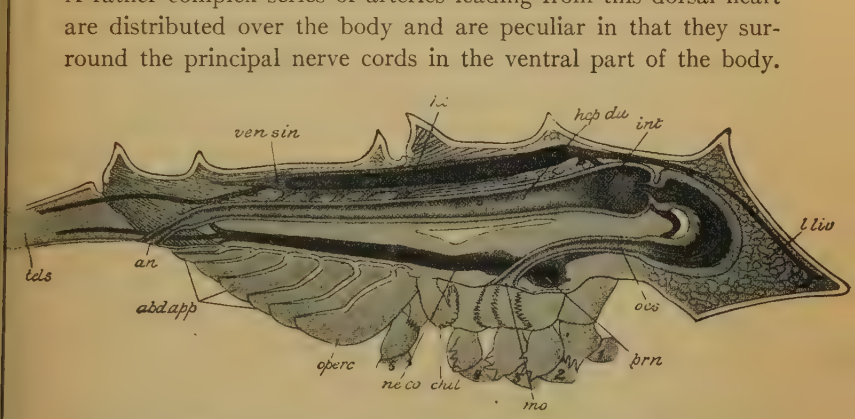


FIG. 126. — Diagrammatic view of a median longitudinal section of **Limulus.** *abd.app*, abdominal appendages; *an*, anus; *brn*, brain; *chil*, chilaria; *hep. du*, opening of one of the hepatic ducts; *ht*, heart; *int*, intestine; *liv*, liver; *mo*, mouth; *ne. co*, nerve cord; *œs*, esophagus; *operc*, operculum; *tels*, telson; *ven.sinus*, venous sinus; *1–5*, legs. (From Leuckart, partly after Packard.)

Blood flowing through the smaller vessels collects in a ventral sinus, from which it passes through the respiratory plates and from these back to the pericardium. The respiratory plates are much folded, each plate including a hundred or more of leaves within which the blood may flow. Water which bathes the gill plates externally provides oxygen for the blood.

The nervous system is quite similar in many respects to that of the arachnids, but this similarity is perhaps simply due to the shunting backward of the mouth opening so that the cerebral and

ventral ganglia are brought close together and lie within the same plane. The anterior ganglia, corresponding with the cerebral of the crayfish, supply nerves to the compound eyes and anterior portion of the body. The ventral ganglia send nerves to the appendages and connect posteriorly with a ventral cord, including ganglia. The compound eyes are large but not stalked, scarcely elevated above the body wall. In front and near the middle line are two simple eyes.

The sexes are distinct, the reproductive organs rather simple, the eggs are produced in spring or early summer, and the development of the young proceeds during the summer season. Growth continues probably as long as they live, and individuals of very different sizes will be found, the largest females measuring sometimes a foot or more across the carapace. The king crabs feed mainly upon worms or other animals which are secured by burrowing in sand or mud. In molting, the external case is shed so completely that it preserves its form very perfectly, and except for its lightness and transparency might be supposed to be an entire animal.

Order Eurypterida. — These were gigantic Arthropoda which existed in very early geologic times, persisting up to the carboniferous age. They had a body of three regions, a small head, six-jointed thorax, and six-jointed abdomen. They appear to be simpler than the Trilobites, and the largest forms known, about six feet in length, considerably exceed the largest known Trilobites.

Order Trilobita. — The Trilobita, though entirely extinct, are among the best known animals because of their great abundance and remarkably perfect preservation in the rock strata of the early geological periods. Appearing in the lowest fossiliferous rocks, they survive until the Carboniferous. The group stands out pretty distinctly from all other animals, but shows affinity to the crustaceans and arachnids. The head is fused into a shield, the thorax contains a varying number of segments which were freely movable, permitting the animal to double itself so that in a great many instances the head and tail portions are found doubled

together. A terminal pygidium apparently represents the abdomen of the Crustacea, while the position of the gills on the appendages perhaps resembles that of Limulus. While possessing great geologic interest the group has no particular economic importance except as the specimens are in the market for cabinet purposes and as their appearance is used as a means of distinguishing geologic strata.

CHAPTER XI

Class Arachnida

The Arachnida, including scorpions, spiders, mites, and ticks, are an extensive group, apparently of ancient origin, and most abundantly represented at present by the various groups of spiders and mites. The different subdivisions are well marked, and we may leave the discussion of typical examples for consideration under each order. There is general agreement, however, in the absence of antennæ and compound eyes, and in the presence of four pairs of walking legs in the adult stages. The mouth parts vary considerably, but usually consist of strong biting mandibles, sometimes modified into piercing organs, as in the parasitic mites. They are air breathing, and the more common respiratory organ is a pulmonary cavity or lung book. In some forms there are extended tubes which resemble the tracheæ of insects, though probably not homologous with them. The body regions are more or less fused, there being commonly a cephalothorax bearing the head appendages and walking legs and a distinct abdominal region which is sometimes segmented. In the mites the abdomen also is fused with the cephalothorax. The nervous system is ventral, a rather large ganglionic ring surrounding the pharynx, and a chain of ganglia located in the thorax and abdomen which is considerably modified in the different groups. Simple eyes varying in numbers occur on the front of the cephalothorax, but may be reduced or entirely lost in the parasitic forms. The circulation varies in different groups, but usually includes a large dorsal vessel. The sexes are distinct and development typically with superficial cleavage.

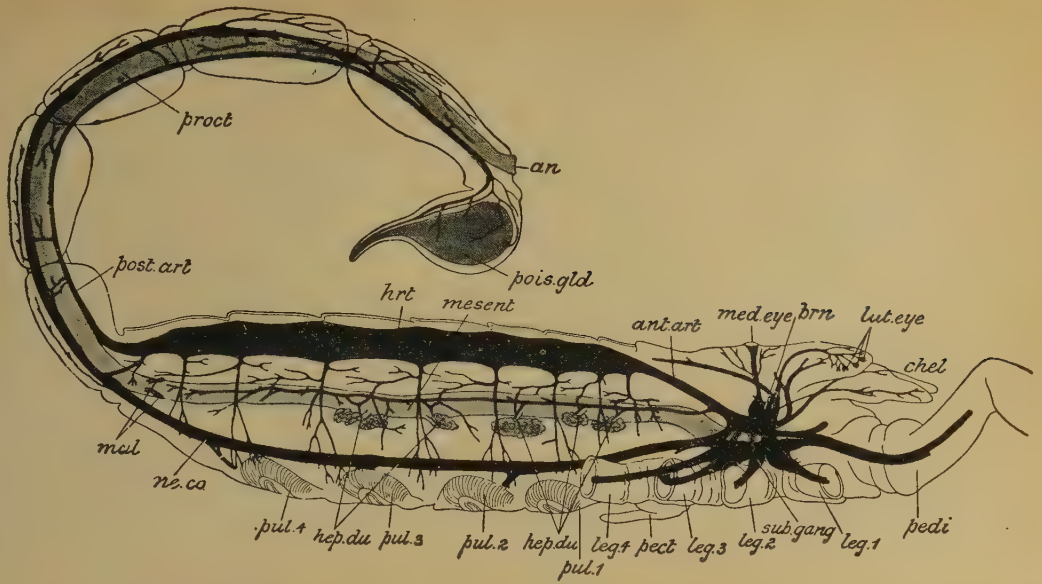


FIG. 127. — Diagrammatic side view of the internal organs of **Scorpion**. *an*, anus; *ant.art*, anterior aorta; *brn*, brain; *chel*, cheliceræ; *hep.du*, hepatic duct; *hrt*, heart; *lat.eye*, lateral eyes; *leg*, *1–4*, legs; *mal*, Malpighian tubes; *med.eye*, median eye; *mesent*, mesenteron; *ne.co*, nerve cord; *pect*, pectines; *ped*, pedipalp; *pois.gld*, poison gland; *post.art*, posterior aorta; *proct*, proctodæum; *pul*, *1–4*, pulmonary sacs; *sub.gang*, subesophageal ganglion. (From Leuckart, after Newport and Blanchard.)

Order Scorpionida. — The scorpions are among the oldest of the terrestrial Arthropoda known geologically, their present distribution being confined to the warmer regions, a few occurring as far north as the southern portions of the United States. They have a broad cephalothorax. The second pair of appendages, or pedipalps, are much enlarged and chelate. The four pairs of walking legs are about equal in size. The abdominal segments form two distinct portions, the anterior seven segments (**pre-abdomen**) being broad, while the six hinder segments (**post-abdomen**) are slender, and the terminal one bears a large poison gland and sting. The sting is venomous and strong enough to be somewhat dangerous to the human species. Its virulence varies with the excitement of the individual, also with the species, and probably somewhat with the size or maturity of individuals, and its effect upon different persons may vary with their susceptibility. While seldom proving fatal, it is serious enough to be avoided. The poison is said to affect particularly the red blood corpuscles.

Order Pseudoscorpionida. — These are minute arachnids bearing close resemblance to the scorpions in the large, widely extended pedipalps, but differing from them in having no post-abdomen and no sting. The cephalothorax is rather short and the abdomen composed of eleven segments. They occur commonly under bark of decaying logs, where they doubtless feed upon small insects. One species is very commonly found amongst old books, where it is supposed to feed upon the book lice, which often occur in considerable numbers within the leaves of unused books or in herbaria or insect collections.

Order Pedipalpi. — The whip scorpions occur in tropical or subtropical regions and differ from the preceding group in having shorter, less chelate pedipalps and elongated, slender first legs. The abdomen is narrow and flattened, and in our *Thelyphonus* of Florida there are three narrowed, hinder segments, the last bearing a long bristle or whip. The eyes are minute, arranged at the sides of the cephalothorax, the lung books are four in number. The cheliceræ contain poison glands and their bite is venomous.

Order Solpugida. — The members of this order are quite exceptional in their structure, having the head and thorax distinctly separate, the abdomen segmented, the chelicerae greatly enlarged and strongly chelate. The pedipalps are slender, resembling the legs, and the first pair of legs is located on the posterior portion of the head. The thoracic segments are three in number, each bearing one pair of legs. They are found particularly in arid regions and occur in both the Old and New Worlds, the species, though few in number, having a wide distribution. One species occurs in the Rocky Mountain region of the United States, but most of the species are found in South America or tropical Asia and southern Europe. From their structure, their scattered distribution, and the few numbers of existing species, it seems that the group was differentiated from the other Arachnida in the remote past, and that the present forms are merely remnants. They are reputed to be poisonous, but poison glands have not been found. They are carnivorous, but too scattered and few in numbers to be of very great economic importance.

Order Phalangida. — The harvestmen, or "daddy-longlegs," are rather grotesque creatures with oval or rounded bodies and extremely long, slender legs. They resemble somewhat the spiders, but the abdomen is not separated from the thorax by a stalk. The front legs are often longer than the others, and appear to be used as tactile organs as well as for walking. Their movements are rather rapid, and they capture flies and other insects for food. They possess a peculiar pungent odor. While resembling spiders somewhat in habits, none of them possess spinning glands, and their respiration is by means of tracheal tubes. They abound in shady places, lying in wait for insects which they capture and from which they suck the body juices, leaving the external parts. So long as they capture obnoxious insects they are, of course, to be considered beneficial, and probably the larger portion of their captures consists of insects that are detrimental or at least of no service to man, so that, in general, the group may be looked upon as worthy of preservation, rather than destruction. The species have

a wide distribution, and the group may be looked upon as being quite old but the number of species is limited.

Order Araneida. — The spiders are the most conspicuous and probably the most widely distributed group of the Arachnida. Their abundance, and especially their web-making habit, renders them conspicuous everywhere. The body is sharply divided into cephalothorax and abdomen by a slender pedicel. The mandibles are large and contain ducts leading from poison glands, but the bite, however, in very few cases is venomous enough to have any importance as a menace to man. One species, *Lactrodectes mactans*, occurring in warmer parts of the United States, is credited with a venomous bite. The respiration is by means of one or two pairs of lung books, and in some cases tracheal tubes. The spinning glands, located near the end of the abdomen, are very characteristic structures, differing in their location and structure from those of any other group. Reproduction is by means of eggs, the sexes are quite distinct, and there is often a wide difference in size between males and females.

A well-known garden spider (*Argiope riparia*), common throughout the eastern United States, may be taken as an example for detailed study, although any of the larger species will answer equally well for determination of general structure. This species occurs amongst shrubbery, sometimes in open fields, where tall grass or other vegetation offers support for its web. It is a large black species with brilliant yellow markings, and the legs, in immature forms, with distinct rings of lighter color. The cephalothorax is clothed with silky white hairs. The abdomen in the female is much larger than the cephalothorax, elongate, ovate in shape, the dorsal surface marked with several pairs of indented points. The cephalothorax bears in front four pairs of small but conspicuous eyes arranged in an irregular square. The large mandibles are at right angles to the cephalothorax, their lips provided with a sharp articulated tooth which contains a slender canal for the discharge of the poison. The palpi are five-jointed. The mouth opening lies on the lower margin between the mandibles

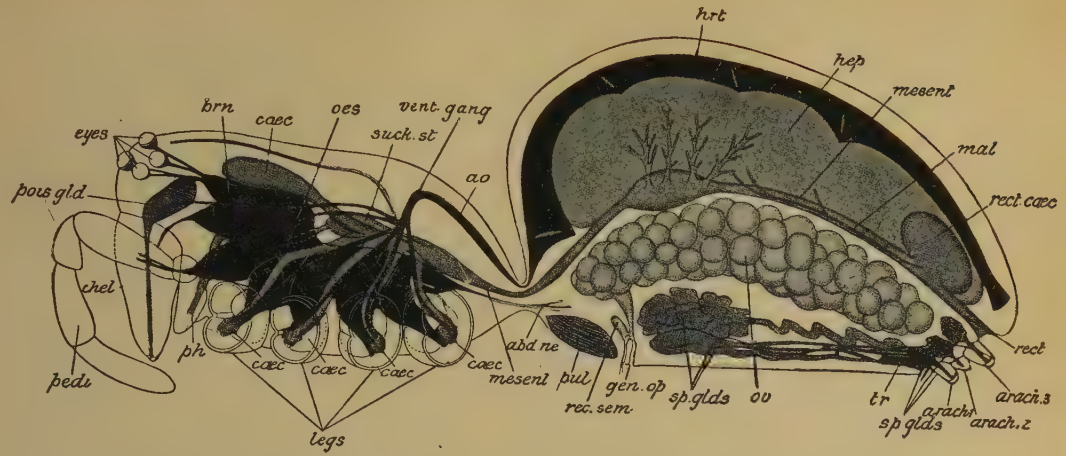


FIG. 128. — Diagrammatic lateral view of the internal organs of a dipneumonous spider. *abd.ne*, abdominal nerves; *ao*, aorta; *arach. 1, 2, 3*, arachnidium; *brn*, brain; *chel*, cheliceræ; *cæc*, cæca; *gen.op*, genital opening; *hep*, liver; *hrt*, heart; *legs*, legs; *mal*, Malpighian tubes; *mesent*, mesenteron; *œs*, esophagus; *ov*, ovary; *pedi*, pedipalpi; *ph*, pharynx; *pois.gld*, poison gland; *pul*, lung; *rec.sem*, receptaculum seminis; *rect.cæc*, dilation of the rectum; *sp.glds*, spinning glands; *suck.st*, sucking stomach; *tr*, trachea; *vent.gang*, ventral ganglia of cephalothorax. (After Leuckart.)

and maxillæ, and is suctorial, the spider pumping out the juices of its victim. The legs arise close together on the ventral side of the cephalothorax, and consist of seven segments each, the basal rounded joint, coxa, articulating in a cavity of the body wall. The joints vary somewhat in length; their names in order are **coxa, trochanter**, **femur**, **patella**, **tibia**, and **tarsus**. The terminal joint is provided with a pair of strong claws. At the base of the abdomen are the openings of the lung books, also the openings of the reproductive organs.

The external openings of the glands from which the web is spun are located at the posterior end of the abdomen, and consist of six apertures, four being located on large papillæ, the other two lying within the space marked by these four. They are called the **spinnerets**, and each opening is composed of very numerous minute apertures, through which the fluid is forced which combines into a thread, and the threads from the different spinnerets unite into a single thread, which is of itself of extreme delicacy, though proportionately extremely strong. The alimentary tract possesses some quite distinct features, the mouth opening behind the ligula, or tongue, extending by the esophagus into a central sucking stomach at each side of which is a stomach lobe, having four long pockets corresponding in position with the legs. At the hinder part of the cephalothorax the canal contracts to pass through the pedicel, expanding somewhat in the abdomen, and extending with little variation in size to the anal opening just behind the spinnerets. Muscles attached to the dorsal and ventral surface of the central stomach provide for the expansion of this organ which makes of it a sucking organ. The blood vessel lies dorsally in the abdomen, forming a rather large vessel having several ostia on the sides, and carried forward into the cephalothorax, where the vessel breaks up and is lost among the tissues of this region. The lung books occupy a large cavity in the anterior part of the abdomen, and the leaves of the book are abundantly supplied with capillaries in which the blood flows for aeration and from which it passes quite directly to

the blood vessel. A pair of tracheæ open posteriorly just in front of the spinnerets and doubtless provide for aëration of the tissues in that region. The nervous system is compact, the cerebral ganglia being closely connected with the ventral ganglia, so that all may be looked upon as a nearly fused mass of ganglia, the anterior part of which is perforated by the esophagus. From the dorsal portion of the cerebral ganglia nerve fibers pass to the eyes and anterior organs of the cephalothorax. From the ventral ganglia nerve fibers are given off to the legs and the posterior part of the body. The spinning glands of two kinds occupy quite a space in the hinder end of the body, and consist of numerous gland bodies, the secretion from which is poured into ducts leading to the spinnerets. The reproductive organs differ little in location in the two sexes, the ovary being in the central portion of the abdomen, the oviduct passing forward and downward and opening behind the openings of the lung book. In the male the testes lie ventrally, the external opening being near the hind border of the lung book. The spermatic fluid is discharged and taken into the terminal segment of the palpus, from which it is transmitted to the spermathecæ of the female, whence it passes later to the small tubes of the oviduct, in which fertilization of the eggs occurs. The males are very much smaller than the females, and are to be recognized by an enlarged palpal segment or, on dissection, by difference in the reproductive organs.

The web spun by this spider is a large structure with a spiral arrangement of thread supported on radial threads, and over the central part of which is usually a broad zigzag ladder-like stretch of close ribbon-like web. The spider commonly rests at the center, ready to dart in any direction when an insect comes in contact with the web. Insects, when caught, are rapidly enswathed in a dense silken envelope, from which they cannot escape, and the spider takes its leisure in sucking the body fluid. Insects as large as good-sized grasshoppers are in this way readily captured and devoured.

The male is much smaller, but similar in shape and marking,

and sometimes may be found near the web of the female, where it spins a weak, imperfect web.

The egg mass is inclosed in a large globular ball, or cocoon, formed in the latter part of summer, and within this protection the winter is passed, the young spiders hatching in midwinter and issuing from the cocoon in May. They grow during early summer and attain maturity by late midsummer.

Spiders in general make webs of various kinds, and the web is used for many different purposes. Among these is the formation of protecting nests, snares for procuring prey, cocoons for their eggs, support in climbing and dropping from a height, and even to provide aerial locomotion in "ballooning." Some lay their snares near the surface, making a broad, flat surface, merging at one edge into a funnel within which the spider is secreted, ready to spring upon any insect enmeshed in the web. A species living on the sand of lake beaches is admirably protected by color and marking. The orb-weaving spiders build beautiful gauzy structures with spiral threads supported on numerous radial stays. The construction may be readily watched. A suitable location is secured, some external threads cast to favorable points of support, a thread drawn from both sides, and then from a central point radial threads attached like spokes of a wheel to the outer circle. When these are in place, the spider runs a wide spiral from center to circumference as a temporary support, and then places a main spiral of viscid threads, beginning at outer margin and working toward the center. As this progresses the temporary spiral thread is cut away.

Sexual dimorphism is conspicuous, the males usually much smaller than the females, often of much brighter colors, very frequently so extremely disproportionate in size and so differently marked and colored that they will not be suspected of belonging to the same species.

In many of the species it is said that the ferocious instinct of the female is applied to the male, and that mating is attended with great hazard, the males being ruthlessly caught and devoured

by their intended mates. One reason assigned for the size of the males is that, on account of this cannibalistic habit, the smaller the male, the more likely he would be to escape capture,

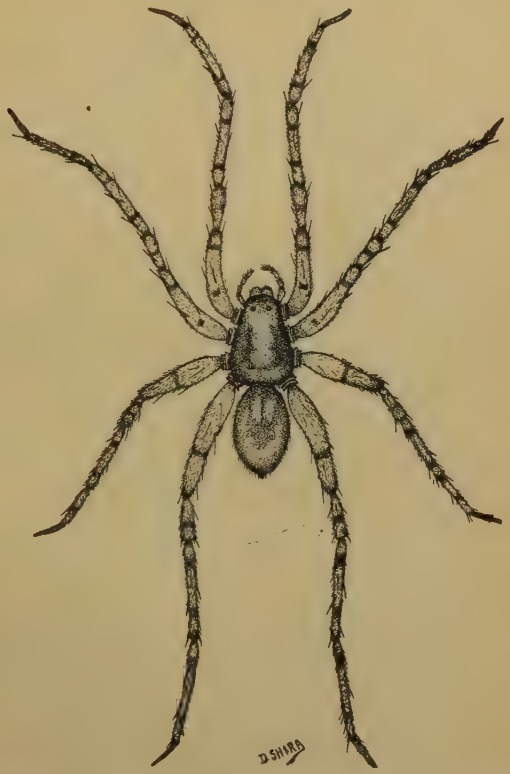


FIG. 129. — **Spider.** Showing markings to protect it on sand. (From drawing by D. D. Shira.)

and hence selection would tend to favor disparity in size. In some extreme cases the difference amounts to a ratio greater than one to a hundred.

Order Acarina. — These are commonly known as mites, ticks,

scab insects, mange insects, etc., and are, in general, distinguished by having no prominent separation between the different regions of the body, the head, thorax, and abdomen forming one closely connected structure. They have eight legs, except in the early stages, when there are but six; the eyes are often small or obsolete, the spiracles, reduced to one pair, sometimes apparently wanting; the mouth parts are adapted for piercing, biting, or in some cases for combined biting and suction, there being usually a pair of slender, sharp mandibles capable of penetrating the skin of the host animals. Much variation of habit exists, and ranges from free to strictly parasitic forms.

The order includes a number of distinct families showing much diversity of habits, one being very distinctly aquatic, another occurring as free and predaceous, still another including many semi-parasitic species and a number that are essentially parasitic, and restricted to very definite hosts.

The aquatic forms are evidently adapted from a terrestrial habit, and in most cases preserve in some degree the features possessed by the terrestrial forms. The lines of divergence in habit have evidently passed from free-living terrestrial forms to distinctly aquatic conditions along one line, and to strictly parasitic conditions along another. In each case very special structures are produced for special functions. Some aquatic forms are parasitic on certain mollusks, one abundant species occurring attached to the mantle of the common river mussel. Accounts of a few of the more important species will indicate the general habits and character of the group.

Harvest mites, " chiggers." In the family *Trombidiidæ*, which includes normally plant-feeding species, we find a few species which have adopted a phase of parasitism that is apparently abnormal and results in extreme annoyance to the animals affected.

Apparently the most abundant species in this country is the *Leptus irritans* of Riley, which is illustrated herewith. This occurs in a large portion of the United States, and occasions during the summer months an enormous amount of suffering. It ranges

north in the Mississippi Valley as far as to the Great Lakes at least, appearing here by the latter part of June or early part of July, but becoming especially annoying during August. In the latitude of Washington it is very abundant early in June, and farther south it occurs earlier still. In southern Mexico, apparently the same species is abundant and equally annoying in January.

The form in which this pest is observed is invariably the larval or six-legged form. It is nearly circular in outline, the legs ex-

FIG. 130. — **Leptus irritans** to the right and **americana** to the left. (After Riley.)

tending well beyond the margin of the body, of a bright red color, and so minute that it is only with the closest scrutiny that it can be detected.

It is brushed from the leaves of various plants to the hands or clothing of people and to the bodies of other animals. The mite then proceeds to burrow into the skin, notwithstanding the fact that, so far as all evidence shows, this proceeding is absolutely fatal to it, and prevents any possibility of its maturing or producing eggs.

Just what form this creature develops into if unmolested and allowed to develop along its normal course seems never to have been determined. It is assumed, however, that it changes into

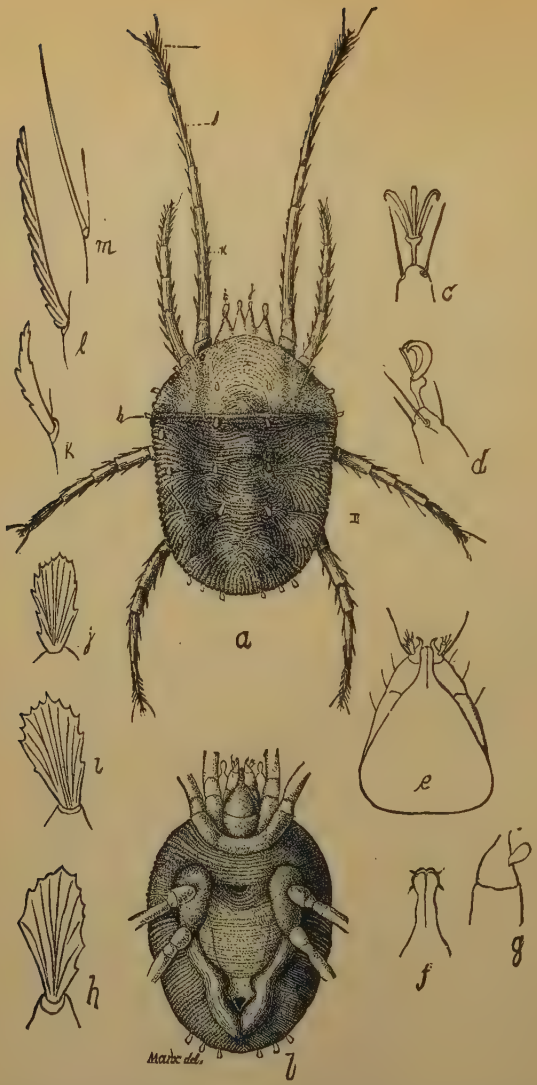


Fig. 131. — Bryobia pratensis. *a*, female from above; *b*, same, ventral view; *c*, *d*, tarsal claws; *f*, proboscis; *g*, palpus; *h*, *i*, *j*, body scales; *k*, *l*, specialized hairs from legs; *m*, spine of last joint. All enlarged. (Howard and Marlatt, Bull. Div. Ent., U. S. Dep. Ag.)

one of the species of *Trombidium*, and is probably the locust mite, *Trombidium locustarum*.

In Europe a similar pest, known as *Leptus autumnalis*, is said to be a great annoyance to man and domestic animals, especially to dogs and chickens.

There is great difference in the susceptibility shown by different persons to the attacks of this mite, some not seeming to be

FIG. 132. — **Dermanyssus gallinæ**. *a*, adult; *b*, tarsus; *c*, mouth parts; *d* and *e*, young. All enlarged. (After Osborn, Bull. Div. Ent., U. S. Dep. Ag.)

affected seriously by them, while others must submit to extreme torture every time they happen to become attacked by them, even if they are but few in numbers.

As the mites are invariably secured by working among raspberries, currants, or other shrubbery which harbors them, or by walking in grass or low herbage where they occur, sometimes even by sitting or lying for a short time upon grass or clover, it is evident that the best precaution for susceptible persons is to avoid all such exposures. Where such avoidance is impracticable, the clothing may be made to fit closely at the wrists and ankles, and

then, as soon as possible after having been exposed to the mites, make an entire change of clothing, bathe in hot water, and if any indications of mites are present, wash the affected parts with diluted carbolic acid, one part acid to fifty or one hundred parts water.

A mite that sometimes becomes very troublesome in houses is the clover mite, *Bryobia pratensis*. It lives on vegetation, especially clover, but in autumn swarms into houses, often to the great discomfort of the inmates.

The poultry tick (*Dermanyssus gallinæ*). One of the most persistent and injurious of the pests of the hennery is the little chicken mite, which gathers on the fowls, especially at night, and sucks their blood. It is a well-known form, and has been described for many years, though in many works it is confused with the bird tick or considered simply a variety of that form. Its distribution seems to extend pretty generally over the world where domestic fowls are kept.

The full-grown mites are about one millimeter long, of a light gray or whitish color, with dark patches showing through the skin, but when full fed of a distinct red color. They swarm in cracks and corners of the henhouse, and often, when numerous, over all surrounding objects, and at such times are liable to become a great pest to man and such other animals as they may get access to.

It is probable that the presence of filth favors their increase, as it would seem possible for them to use fluid matter as food aside from the blood of their ordinary hosts.

The dust bath is considered of use in checking this pest, but where there is a general infestation, clear the house, then spray well with kerosene or kerosene emulsion, taking pains to reach the cracks; thoroughly drench the roosts with hot water or kerosene, benzine, or gasoline, whitewash the house, or dust with carbolated lime, and then daub the ends of the roosts where they come in contact with supports, with coal tar, so that the mites will have to cross it to reach the fowls.

The cattle tick (*Boophilus annulatus*) is without question the most important species and presents three different phases of injury,—first as a direct parasite, second as furnishing a source of attraction for the screw-worm fly, and third as the essential carrier of the protozoan disease, Texas fever.

The tick is a reddish, flattened species, and, when gorged with eggs, sac-like with a constriction behind the middle. The mouth

FIG. 133. — Boundary line of the district infected with Texas fever. (Bu. An. Ind., U. S. Dep. Ag., 1905.)

parts are large and furnish a strong hold in the skin, where the tick is anchored so firmly that if pulled away the mouth parts are often broken, or a small patch of skin is torn away. Its sole food is the blood of the host, and it loosens its hold only at times of molting, or, for males, at time of mating, when the females are sought. The eggs drop to the ground, and on hatching, the young crawl upon leaves of grass or foliage of near-by plants and attach themselves at the first opportunity to some passing animal. Thereafter they remain tenaciously upon this host.

This dependence of the tick on a host for its existence, even in the early stages, gives a basis for the successful eradication of the pest and with it the scourge of Texas fever. By arranging for an alternation of pastures or fields in which cattle are kept, so that each field will be unoccupied by cattle during a certain period, and so that cattle will be placed successively on land that has not been occupied by cattle, and hence tick free, the entire herd may

FIG. 134. — Cattle tick. Above, female, natural size, side view; below, dorsal view, male, enlarged. (From Packard.)

FIG. 135. — Itch mite (**Sarcoptes scabiæi**). (After Leuckart.)

be rendered tick free within a single year. The time for the eggs to hatch and the young to perish from starvation varies at different seasons and temperatures, and hence periods exceeding this should be allowed before any stock is introduced into the field.

The itch mites or mange insects form a family of strictly parasitic forms; that is, forms which are dependent during their existence upon a particular host animal. They live on the surface of the skin, burrow into its tissues, in some cases live within the quills of feathers, and in a rather extreme form burrow within the skin and attach to the blood vessels of the neck region in certain

birds. The species are numerous, and such diseases as the itch in the human species, in dogs, cats, etc., are due to them.

The most important species at the present time is undoubtedly the one producing the disease known as scab in sheep, *Psoroptes*

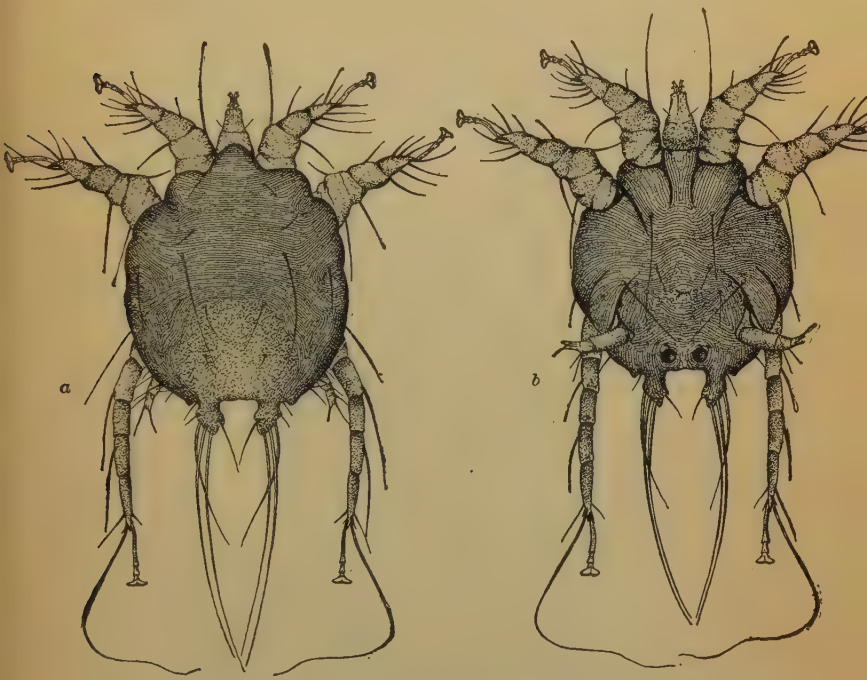


FIG. 136. — Adult male parasite of common sheep scab (greatly enlarged). *a*, view from above; *b*, view from below. (Farmers' Bull., U. S. Dep. Ag.)

communis var. ovis. This species affects sheep, cattle, and horses, a distinct variety occurring on each one of these animals, but the one affecting sheep is most serious. Its distribution is at present practically over the entire world where sheep are reared, and the control of the disease requires constant effort and the enforcement of rigid laws for the quarantine and treatment of infected sheep.

It has been entirely eradicated in a few western states by such measures.

The eggs of this mite are minute, glistening, white specks, longer than broad, and nearly uniform in thickness. They may be found under the scabs, and their detection, even when mites are not seen, may be taken as evidence of the disease.

The larvæ have nearly the shape of the adults, but are to be distinguished by the fact that only six legs are apparent.

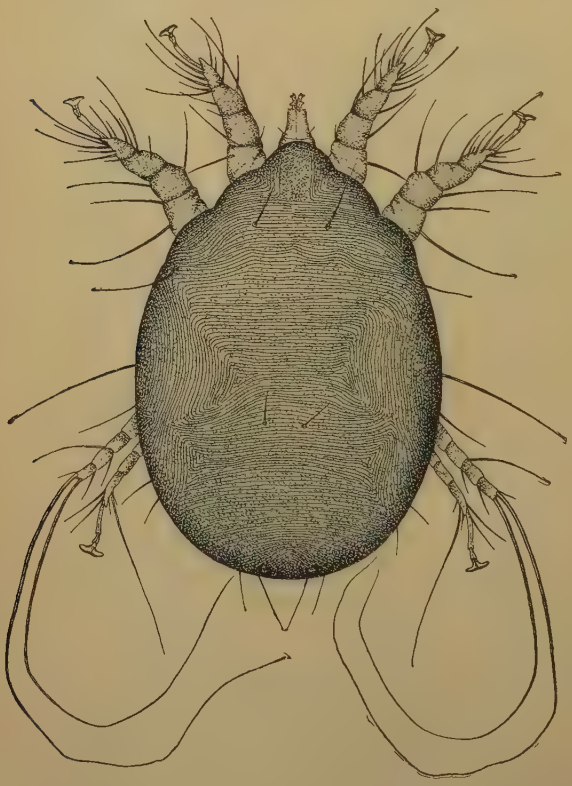


FIG. 137. — Adult female parasite of common sheep scab (greatly enlarged). *a*, view from above. (Farmers' Bull., U. S. Dep. Ag.)

The full-grown mites are nearly as broad as long, and are characterized by their piercing mouth parts and the structure of the two posterior pairs of legs (see Figs. 136, 137, 137*a*). In the male, the fourth is much reduced, and the third bears a long thread-like appendage passing the sucker, while in the female this leg carries two long thread-like organs and no sucker.

The only treatment for this species worthy of recognition is that of dipping, and this, if properly done, will secure the extermination of the pest. A flock, once freed, will not become infected

FIG. 137*a*. — Adult female from below. (Farmers' Bull., U. S. Dep. Ag.)

again except by exposure to infected animals or by the introduction of scabby individuals to the flock.

The follicle mites (*Demodex folliculorum*) are rather degenerate, worm-like forms that occur in the hair follicles of different animals, the variety occurring on man (*hominis*) producing the little specks or blackheads so frequent on the face, and which are said to be almost universally present, though it is seldom they

FIG. 138. — An advancing case of common scab. (Farmers' Bull., U. S. Dep. Ag.)

cause any special irritation. The variety occurring on dogs (*canis*) produces serious disease, as does also the one on hogs (*suis*). In both these animals the affected parts are the face and nose and occasionally larger tracts of the body. The variety on cattle (*bovis*) affects the body at large and has a somewhat different interest, as it is recorded as damaging the hides for market. The mites evidently undergo all stages of development in the follicles, but doubtless migrate over the surface of the skin when mature and before laying eggs. The use of dips and washes would seem

to be the only sure treatment for domestic animals, and if it is thought necessary, a similar mode could be adopted for man.

Another extreme form (*Phytoptus* and allied forms) produces galls, distorted growths, sometimes immense brush-like growths called "witch's broom" on trees and various plants.

Order Linguatulida. — These are degenerate arachnids so much modified from the typical forms that they were long supposed to belong to other groups. The development through a larval stage which shows the definite arachnid structures, however, proved beyond question the true relationship. The adults are footless, with two pairs of hooks at the sides of the mouth. The organs of circulation and respiration are rudimentary. The most common species is a parasite which alternates between the dog and horse as its hosts.

The worm-like condition of this parasite may be inferred from the fact that it was originally described as a tapeworm (*Tænia rhinaria*), but its arachnid affinities were early suspected, and, with the determination of the early stages, were proven beyond question.

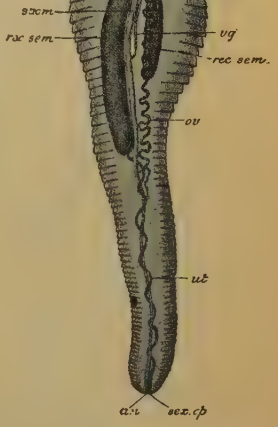


FIG. 139. — **Pentastoma tænioides.** Young female. *an*, anus; *gang*, ganglion; *hk*, hooks; *mo*, mouth; *œs*, esophagus; *ov*, ovary; *ovd*, oviduct; *rec.sem*, receptaculum seminis; *sex.ap*, sexual aperture; *stom*, stomach; *ut*, uterus. (After Leuckart.)

In the adult worm-like stage it is a parasite in the nasal cavities of various animals, especially carnivores, the most common host, perhaps, being the dog. The larval state occurs in the viscera of different animals, but more particularly those which are herbivorous — the horse, sheep, ox, goat, and many others, as well as man.

The migrations between these hosts, which are evidently an essential part of its existence, may be stated in brief to be the discharge of numerous eggs in the nasal cavities of the dog or other host, which, in sneezing or coughing, spreads them over vegetation that later is taken as food by some herbivorous animal: and, following this ingestion, the embryos escape into the glands and viscera of the new host, occupying especially the mesenteric glands, liver, etc., where they remain in an inactive condition until fragments of the viscera containing them are eaten by a carnivore, when they gain access to the nasal cavities and become mature. In case they do not have the fortune to be eaten by a carnivore, it is believed they may migrate within the body of their herbivorous host, reëncyst themselves in other organs, and even in some cases reach the nasal cavities by way of the lungs and air passages, thus accounting for the rare occurrence of the adult form in a herbivorous host.

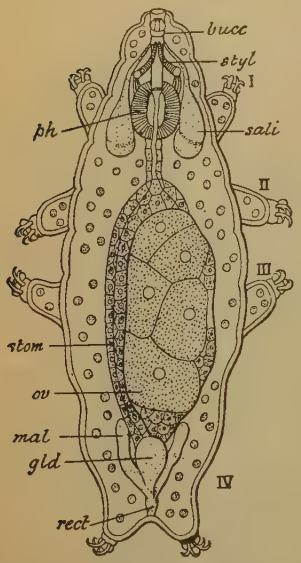


FIG. 140. — **Macrobiotus hufelandi.** I–IV, appendages; *bucc*, buccal cavity; *gld*, accessory gland; *mal*, Malpighian tube; *ov*, ovary; *rect*, rectum; *sali*, salivary glands; *stom*, stomach; *styl*, teeth. (After Greef and Plate.)

Order Tardigrada. — These minute microscopic animals, the water bears, are of doubtful position, but on account of certain structures seem to belong to the arachnids, being probably a specialized or degenerate offshoot from the main group. The body is without segments, appears worm-like, but there are four pairs of short stumpy appendages, terminating in distinct claws. The mouth parts are adapted for puncturing and sucking. They occur in water or

sometimes in damp moss, but always where there is sufficient moisture to provide for their activity. They withstand drying very successfully, but of course are inactive during periods of desiccation.

Order Pycnogonida. — These, again, are quite aberrant forms, remotely related to the arachnids, their specialization taking the form of adaptation to marine life. All the species live in sea water, some near shore and amongst sea weeds, corals, etc., others at great depths. There is a slender trunk, or cephalothorax and an aborted or rudimentary abdomen. The appendages consist of a pair of mandibles, a pair of palps, a pair of slender legs, egg-bearing if present in the female, and four pairs of walking legs. The alimentary canal is provided with cæca which extend into the legs a considerable distance. No respiratory organs are present and respiration doubtless takes place through portions of the body wall. No economic importance is attached to the members of the group.

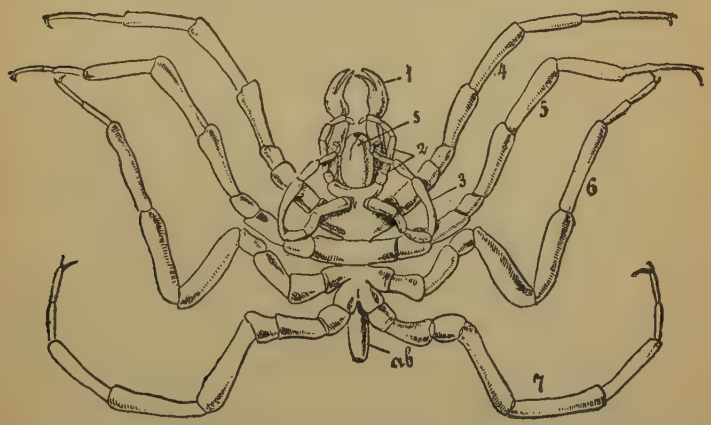


FIG. 141. — **Nymphon hispidum.** *1–7*, appendages; *ab*, abdomen; *s*, proboscis (After Hoek.)

CHAPTER XII

Class Protracheata

The animals included in this division are of special interest because they seem to present us with the simplest types of existing animals in which tracheal respiration is present. We may imagine that they represent the living descendants of an ancestral form which was the first to adapt itself to air breathing as a part of the condition of terrestrial habit, and that from such an ancestral form have been derived the present members of this group,

Fig. 142. — **Peripatus capensis**, lateral view. (From Balfour.)

the extensive groups of Chilopoda, Diplopoda, etc., and, most important of all, the immense group of insects, which by extreme specialization and particularly the acquisition of wings, has outstripped all other groups of invertebrates.

The essential characteristics of the group consist of an elongated segmented body with paired appendages, in which external segmentation is not apparent, one pair of antennæ, a respiratory system consisting of numerous spiracles opening into divergent respiratory tracheæ, a series of segmental nephridia, an elongated dorsal heart, and a pair of ventral nerves similar in location to those of the Nemertean.

The typical genus *Peripatus* contains a number of species widely distributed, occurring in the West Indies, Central America, South America, Africa, Australia, and New Zealand — a distribution

which may be interpreted as indicating great antiquity and a former wide distribution with extinction in intermediate regions. They are seldom observed except by naturalists, as they hide under stones and in the debris of tropical forests, but are said to be very beautiful when alive in the velvety textures as well as the coloration of the body. They are about two to three inches long, rather

FIG. 143.—Ventral view of head of **Peripatus capensis**, with antennæ, jaws, oral papillæ, and first pair of legs. (After Balfour.)

slender; the head bears a pair of segmented antennæ, a pair of preoral slime-secreting papillæ, and sickle-shaped jaws. The body appendages vary in number in different species.

The legs are segmented in the larvæ, but in the adults this segmentation is lost.

Locomotion is somewhat vermicular, there being an external layer of circular muscles, an internal layer of diagonal muscle

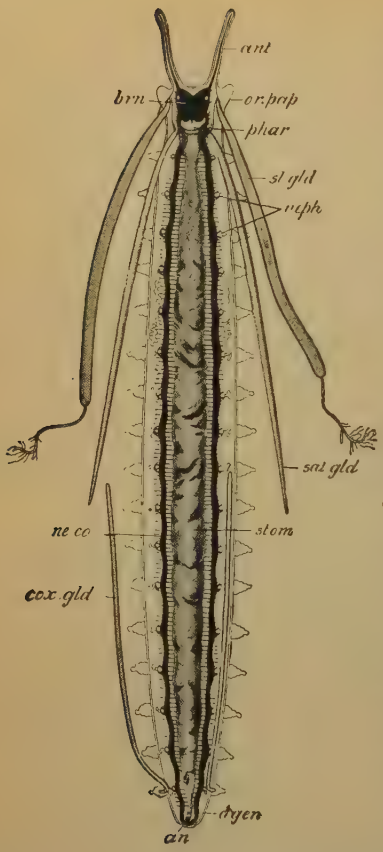


FIG. 144. — Dorsal view of the internal organs of **Peripatus**. *an*, anus; *ant*, antennæ; *brn*, brain; *cox.gld*, coxal gland of the seventeenth leg; ♂ *gen*, male genital aperture; *ne.co*, nerve cord; *neph*, nephridia; *phar*, pharynx; *sal.gld*, salivary gland; *sl.gld*, slime gland; *stom*, stomach. (Combined from Balfour.)

fibers, and a deeper layer of longitudinal fibers. The muscles of the leg being comparatively weak the movements of the legs probably serve more for attachment than for active locomotion.

The alimentary canal extends throughout the length of the body without very marked separation into distinct parts. The mouth is provided with two large jaws which move laterally. There is a muscular pharynx connected with two large salivary glands which are elongated in form and extend back a considerable distance in the body. The terminal portion, or proctodæum, is very short, forming a rectum, and terminates at the extreme posterior end in a small anal opening.

A slender dorsal blood vessel lies next the body wall and is inclosed in a pericardial space which receives blood from the body spaces. A series of valvular openings lead into the tubular heart, in which rhythmic contractions propel the blood in a forward direction and from the anterior portion it circulates in irregular spaces throughout the

tissues. Correlated with this rather simple circulation is a well-developed respiratory system consisting of numerous minute but unbranched tracheal tubes, a number arising together from a cavity connected by a spiracle with the external air. Spiracles in some of the species are arranged in definite rows, dorsally and ventrally, but in other species are scattered irregularly over the body.

The excretory system is of special interest because of its close resemblance to the nephridial system of annelids. Nephridia occur in pairs in each segment and have a very similar structure to those of the earthworm. The slime glands, opening in the head-papillæ, and the crural glands, occurring in the legs and opening externally, are structures whose homology has not been determined positively, but the former functions in the secretion of slime. The nervous system, while occupying a ventral position and connecting above the esophagus with a rather large cerebral ganglion, differs from that of other arthropods in having the ventral cords widely separated, the ganglia but slightly larger than the nerve cord, and the two cords connected by numerous transverse commissures. Laterally numerous fibers are given off to the muscles and legs. The antennæ are supplied with nerves from the cerebral ganglia; and the two simple eyes, located dorsally, are likewise innervated from the same source. The eyes are quite unlike the compound eye of the more specialized tracheates, but possibly homologous with the eyes of marine Annelids. The reproductive organs consist, in the female, of two closely fused ovaries, the ova from which pass along slender oviducts, and thence into the uteri which terminate in the median ventral line in the next to the last segment. The testes are rather large, the vasa deferentia terminating in a common duct opening in the last segment in front of the anus. The eggs develop on a somewhat unusual plan in some forms, but in others on the superficial cleavage arrangement of the arthropods generally. In the *P. capensis*, it is said, the ovum during division does not exhibit the usual cell limits, but is a simple protoplasmic mass, and even when the body is formed,

the continuity of cells persists. These features seem, however, rather to be connected with specialization than to stand for a primitive form of development.

As stated, the group is of particular interest from its apparent primitive character, and it is especially striking in the possession of a nephridial system which appears strictly homologous with that of the annelids, and on the other hand the tracheal system, while slightly different from that of the insects, seems quite certainly to be homologous with it and really to be the primitive form of tracheal system from which the more complex plan of myriapods and insects is derived. As for the nervous system, it may be looked upon as still more primitive than that of the earthworm, or the divergence of the ventral cords may be in part a specialization in one direction, while the close approximation of cords and fusion of ganglia in the earthworm and in the higher arthropods has a specialization in the opposite direction. Whatever their relationships, we must assume that they belong to the remote past and that the existing forms, though perhaps slightly modified from the ancestral types, are a survival of a group which in the main has been lost, although it may have given rise to more specialized groups.

Class Myriapoda

This class, including the centipedes and millipedes, is characterized by the elongated body, the segments of which are uniform except the head and anal segment, each being provided with pairs of appendages of nearly equal size and similar character. The head is composed of several segments and bears a pair of antennæ, and several small eyes on each side. The mouth parts consist of a pair of mandibles and two pairs of maxillæ. There is no distinction between thoracic and abdominal segments, each segment possessing a pair of segmented legs, or in the case of the millipeds (*Diplopoda*) each apparent segment bearing two pairs of legs which arise near the median ventral line. The alimentary canal is rather simple, the circulation carried on in a delicate dorsal

blood vessel, and the respiration provided for in a large number of branched tracheæ, the external openings or spiracles being located on the sides, either one or two to each segment. The nervous system consists of a ventral chain of ganglia of the usual arthropod pattern; the sense organs are not conspicuously developed; the simple eyes, while several in number, must have a slight range of vision; organs of hearing are not known to be present; the senses of taste and smell are probably fairly well developed, and the tactile sense must be present at least in the antennæ. The group is divided mainly on the number of appendages to the segment and the position of the legs; but since the two pairs of legs are correlated with two pairs of spiracles to each segment, we know that each apparent segment in Diplopoda is in reality two segments fused together. The orders into which the class is divided are widely separated, and it has been proposed to dismember the group Myriapoda, giving class rank to these orders.

FIG. 145. — **Scolopendra, or centipede.** (From Cuvier's *Animal Kingdom.*)

Order Symphyla. — In this division are included the most primitive forms of myriapods. The body segments are not more than twelve in number and there is a single pair of branching tracheæ.

Order Chilopoda. — The characteristics of this order are — segments usually 15 to 21 or as high as 173, a pair of appendages to each body segment, body flattened, appendages located near the outer margin separated by a broad sternite. The fifth pair of

appendages, or first thoracic, are modified and include poison glands, from which in some species a venomous poison is discharged. The species are carnivorous and a number of tropical species are decidedly venomous. One occurring in southern United States, *Scolopendra heros*, reaches a length of five to six inches, and a width of nearly one half inch, and its bite may cause serious inflammation, seldom, however, proving fatal.

A quite striking species is the house centiped, *Scutigera forceps*, which has very long legs, the posterior pair being the longest and simulating the long antennæ, which project forward. Several small common species occur under stones or in moist places in the northern part of the United States, and the group is represented throughout the world, especially in tropical regions. The largest known species, *Scolopendra gigantea*, which reaches from nine to twelve inches in length, occurs in the East Indies. A South American species, *S. morsitans*, is nearly as large.

Order Pauropoda. — This group, characterized by the small number of segments, has been established to include the genera *Pauropus*, *Eurypauropus*, etc., which are obscure forms, but which seem to stand in an intermediate position between the other groups.

Order Diplopoda. — In this group, the body is cylindrical, the legs, apparently two pairs to each segment, arising close to the middle line below, scarcely separated by the very narrow sternite. Some forms are slightly flattened, but in many species the rings of the body are almost perfectly cylindrical. The segments are numerous, and the term "thousand legs," commonly applied to the species, is expressive, although the number of legs may in reality be less than one tenth of that number. The large species of *Spirobolus* occur widely scattered over the earth, a species common in the northern United States being *Spirobolus marginatus*, which resembles pretty closely the *terrestris* of Europe.

While the myriapods are on the whole of small importance economically, the species which are venomous have an importance in localities where they occur, and on the other hand their destruc-

tion of other insects may at times be of advantage. The millipeds, while herbivorous, feed largely on refuse vegetable matter, a few only attacking vegetation in such manner as to be of any injury to crops. On the whole they appear to be a rather ancient group, the members of which have long since established their position in nature, and partly because of their rather inconspicuous and unimportant position have survived, while many other forms have become extinct.

Insect orders -
Char. of each order.
Members of each order.

CHAPTER XIII

Class Insecta

Insects constitute the largest of all groups of animals in number of species, and in spite of the fact that they are mostly small in size, occupy a most important position among other forms of life. The relation of injury or benefit to other forms of life, and particularly their injury or benefit to man, mark them the world over as of the highest interest. Essentially they are segmented animals with the body divided into three well-marked regions, head, thorax, and abdomen; the head bearing a pair of antennæ, compound eyes, ocelli, and mouth parts; the thorax bearing the locomotor organs, or legs, and usually wings; the abdomen being without appendages, except those connected with the genital apparatus in the terminal segments. The circulation is simple; the respiration based on a complex series of tracheal tubes opening to the surface through spiracles; the nervous system of the Arthropod pattern, but usually specialized toward the head region; the sense organs usually well developed; the sexes distinct, and reproduction in some cases greatly specialized. The insects in most groups pass through a distinct metamorphosis, the successive being egg, larva, pupa, and imago.

The general structure may be illustrated by such a common form as the grasshopper. One of the available species throughout a part of the United States is the differential grasshopper (*Melanoplus differentialis*). This is a large olive-green species which abounds in grassy fields along fences and roadsides during autumn; and in September and October adults may be taken in great numbers. At this season the females are depositing eggs and may be seen selecting hard ground and burrowing with the

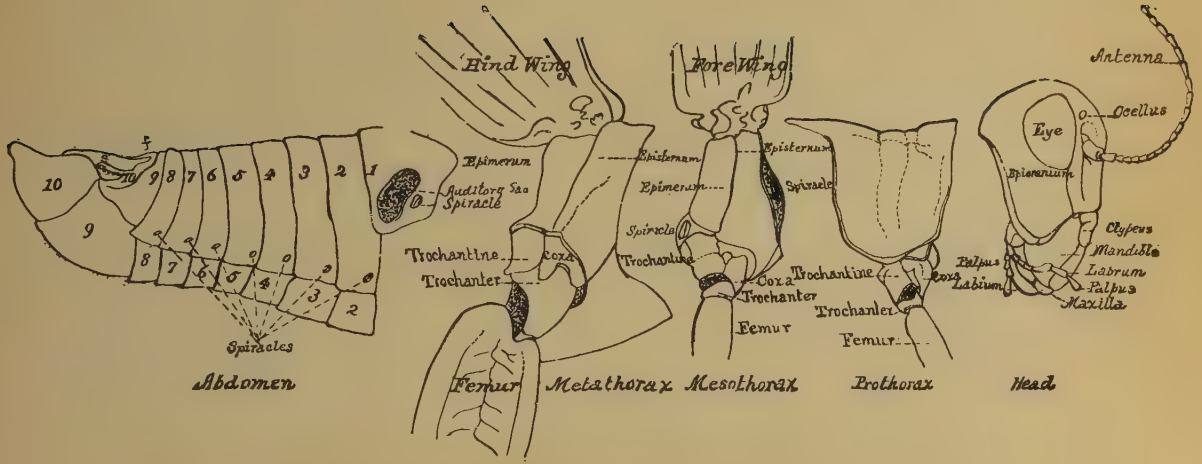


FIG. 146. — External anatomy of a grasshopper, **Melanoplus**, with parts separated. (From Packard's *Text-book of Entomology*.)

abdomen to a depth of an inch or an inch and a half to deposit the large mass of elongate whitish eggs. Other species are plentiful, and any of the larger ones may be used for dissection, the structure in general being so similar that a description of one species will apply to all. The head, thorax, and abdomen are connected by broad attachments, the **head** apparently composed of one segment, the **thorax** of three segments somewhat fused together, and the **abdomen** of nine or ten distinct segments. The head bears a pair of antennæ much shorter than the body, composed of about twenty-three segments of quite uniform size. The **compound eyes** are large, located at the sides of the head, and can be seen with a lens to contain numerous **facets**. The **ocelli** are three in number, one near the base of each antenna and one in the center of the front. At the lower part of the face is the **clypeus**, to which is attached a movable flap, the **labrum**, and underneath which is the pair of strong **mandibles**, followed by a pair of more slender **maxillæ** which bear jointed **palpi**. Beneath these parts is the **labium**, probably homologous with the second maxillæ of Crustacea, the median borders being fused. The **prothorax** projects somewhat over the mesothorax and bears the first pair of legs. The **mesothorax** is short above, longer beneath, with a broad sternum, and bears the first pair of wings. The legs are composed of a series of segments which are highly specialized, the basal segment, or **coxa**, articulating with the thorax, the **trochanter** connecting **coxa** with the **femur**, which is large and long and which is followed by the **tibia**, a slender spiny segment bearing on its distal portion the **tarsus** composed of three segments, the last bearing a strong pair of claws. Between the claws lies a cushion-like structure called the **pulvillus**. The hind pair of legs is much enlarged, the femur and tibia long, the femur having a large muscle which furnishes power for the immense leaps the grasshopper is capable of making. Spiracles occur on the hind border of meso- and metathorax.

The abdominal segments are similar to each other except that the first is incomplete, the pleural portion being attached to the

metathorax and bearing on each side a large membranous disk, the so-called auditory organ. The eighth segment is provided

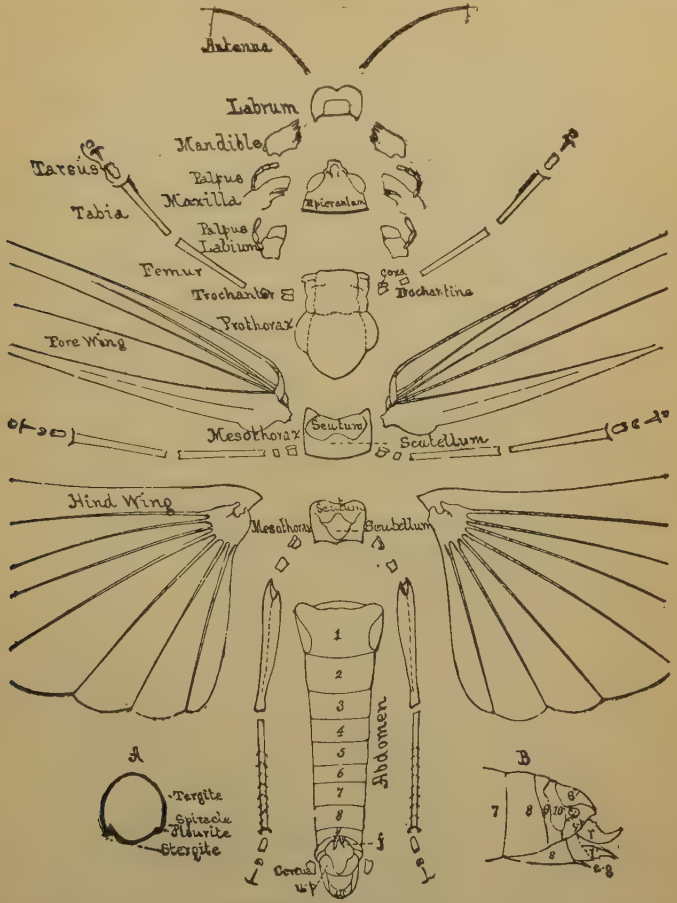


FIG. 147. — Anatomy of a grasshopper, **Melanoplus**, side view. Body regions separated and parts indicated. (From Packard's *Text-book of Entomology.*)

with small appendages, the **cerci**; the ninth segment in the female is provided with two sharp curved structures forming the **ovipositor**, the male having the lower part of this segment inflated,

convex, and followed by the rounded tenth segment. Minute openings, the **spiracles**, connecting with the respiratory system, occur on segments one to eight, and may be seen just above the separation between pleurum and sternum. The alimentary canal is considerably specialized, the esophagus widening into a large crop, the walls of which are provided with chitinous tissue, the stomach being provided with eight pairs of pouches, **gastric cæca**; the intestine being separated into an **ileum**, **colon,** and **rectum**. The salivary glands open into the mouth, the gastric glands into the stomach, and rectal glands into the rectum. The excretory system consists of numerous thread-like **Malpighian vessels,** which open into the intestine. The circulatory system consists of a slender, delicate tube lying next the dorsal wall and so delicate that it is seen only by very careful dissection. The tracheal tubes, however, are very conspicuous, and may be traced as short trunks passing from the spiracles to longitudinal trunks paralleling the walls of the abdomen, the minute branches interlacing throughout the different tissues, the large trunk spreading from each thoracic spiracle and furnishing branches for the tissues of thorax and head. The cerebral ganglion is large, lies between the compound eyes, furnishes large nerves to these organs, and smaller branches to the ocelli and antennæ, and connects with the subesophageal ganglion. From this fibers pass backward into the thorax, in which the three ganglia are brought near together and from which cords extend backward into the abdomen, where we find seven ganglia corresponding with the segments except for the posterior region. The thoracic and abdominal ganglia give off nerve fibers to supply the various organs and tissues. The compound eyes and ocelli are unquestionably organs of vision, the tympanic membrane on the first segment of abdomen quite certainly an organ of hearing, while smell and taste are evidently located in special nerve terminations of the mouth and appendages. The tactile sensation is doubtless specialized in the antennæ and the tactile part of the palpi, and possibly in the tarsi. The reproductive organs lie in the dorsal portion of the abdomen,

the ovaries becoming very much distended with the development of eggs so as to be very conspicuous in autumn. They connect by rather slender oviducts with a common duct or vagina lying in the floor of the terminal segments, the external opening of which is at the base of the egg guides, or ovipositors. The testes occupy the same relative location as the ovaries, but are less conspicuous. The vasa deferentia pass downward and backward, uniting in a common duct, the termination of which is at the base of the tenth segment. The eggs deposited in the earth in autumn remain unhatched until the following spring, when they give rise to larvæ that resemble the adults in general form but have very large heads and no wings. By successive molts of the outer skin and periods of growth they assume the adult form, and with the final molt acquire fully developed wings.

General Structure

With the structure of the grasshopper in mind, we may proceed to consider some features in the structure of insects in general based on modifications from the general plan presented in this insect. While the grasshopper is not the most primitive form of insect, it, or the cockroach, presents us with about as many generalized features as any of the winged insects which are everywhere available for study.

The details of structure among insects, while complicated and their study possibly somewhat tedious, have a definite importance as a basis for the separation of the different groups, for a recognition of the adaptations for the varied conditions of life, and also as a most necessary foundation for a scientific control of those forms which are inimical to human interests.

The body regions, head, thorax, and abdomen, are very constantly represented in all forms of insects, and there appears a tendency in higher or more specialized groups to a more complete separation of these, the head in many forms being connected by a very slender neck to the thorax, and abdomen and thorax

often united, as in wasps, by a slender pedicel. Often the segments are reduced or modified or so fused that they appear to be fewer in number, and in some cases the terminal abdominal portions are telescoped within other segments of the abdomen so the number appears much reduced. The head always appears as a solid single segment, but studies of the embryo in widely different groups of insects, as well as recognition of the homology of head appendages, has shown that the head is composed of six or seven segments. These have been termed the ocular, including the compound eyes, the antennal, the pre-mandibular, the mandibular, maxillary, second maxillary or labial; and, if seven are to be recognized,

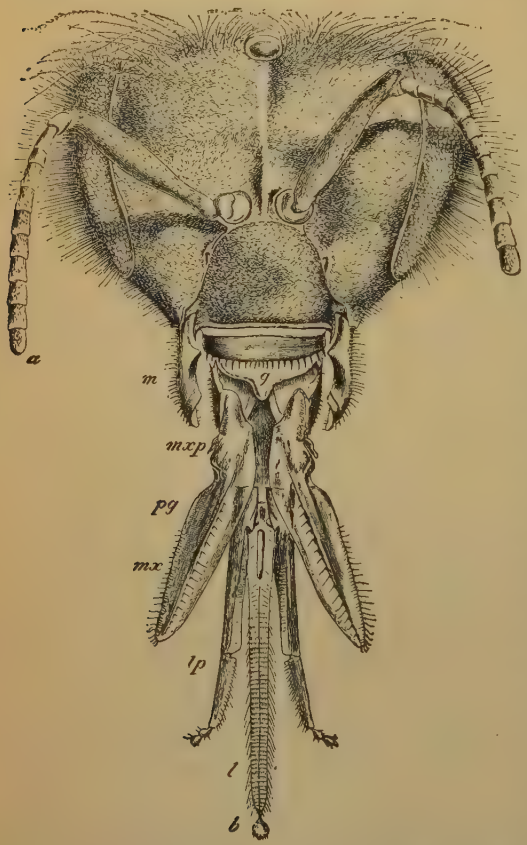


FIG. 148. — Head and tongue of **Apis mellifica** worker (magnified twelve times). *a*, antenna or feeler; *m*, mandibula, or outer jaw; *g*, gum flap; or epipharynx; *mxp*, maxillary palpus; *pg*, paraglossa; *mx*, maxilla, or inner jaw; *lp*, labial palpus; *l*, ligula, or tongue; *b*, bouton, or spoon of the same. (Reduced from Cheshire, after Benton, Bur. Ent., U. S. Dep. Ag.)

there is the superlingual, interposed between the mandibular and maxillary. These segments are correlated not only with external appendages or embryonic rudiments of appendages, but also with the primitive appearance of nerve ganglia (neuromeres) of the head region. The thoracic segments are almost invariably of the primitive number, but in some cases two segments are fused together, and in some of the higher forms an abdominal segment is fused to the metathorax.

The compound eyes, almost invariably present, show considerable diversity of size, are often borne on a short protuberance of the head, the number of facets varying enormously, and in dragon flies running up to thirty-five or forty thousand. The ocelli seem to be primitively three in number, but are often reduced to two and in many groups entirely wanting.

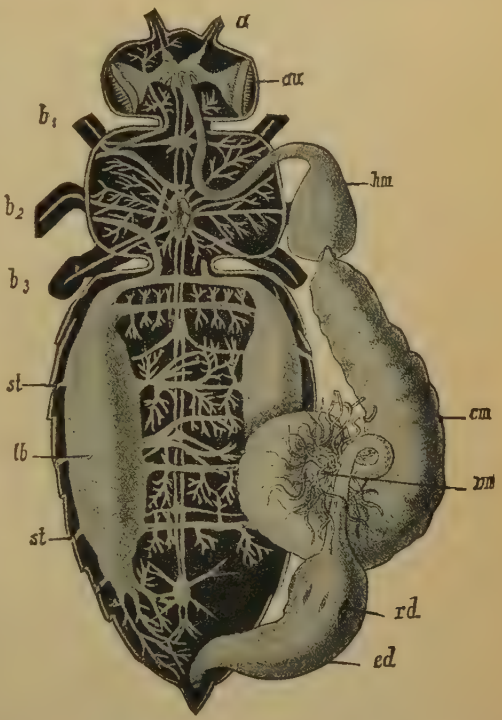


FIG. 149. — Nervous, tracheal, and digestive systems of the honey bee. *a*, antenna; *au*, compound eye; b_1, b_2, b_3, the three pairs of legs; *cm*, chylific ventricle; *ed*, hind gut; *hm*, honey stomach (crop); *rd*, rectal glands; *st*, stigmata; *tb*, vesicle of tracheal system; *vm*, Malpighian vessels. (From Lang's *Comparative Anatomy*.)

The antennæ show an enormous amount of modification, possess important sense organs, and often present most important characters for separation of groups. Their primitive form is a series of uniform segments, or possibly a slender setaceous form such as that of the cockroach. In many groups the number of segments remains very constant and the segments may be inflated, flattened, bead-like, saw-toothed, or comb-toothed; may bear hairs or bristles or feathery appendages; may taper to a fine point or be expanded apically into a club or ball; and may carry organs of touch, smell, and hearing.

The mouth parts are greatly modified in different groups, especially with reference to different kinds of food, and in many

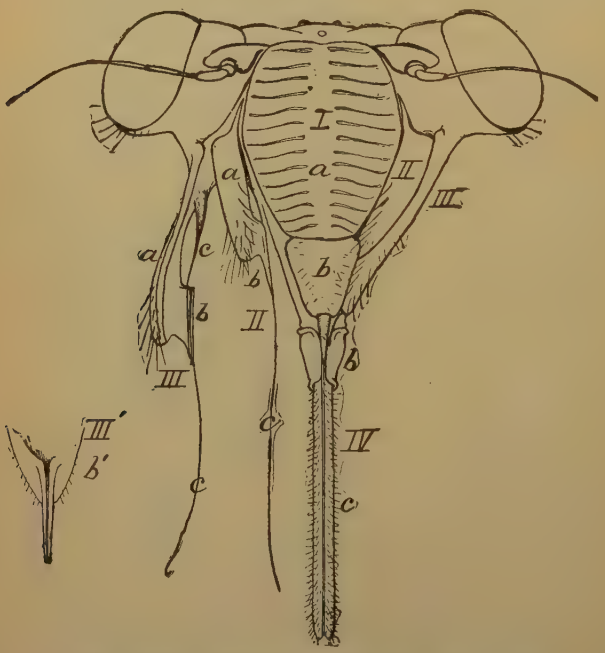


FIG. 150. — Head of **Cicada**, front view, showing the normal position of mouth parts on the left, and with the mandible and maxilla drawn out on the right. For description see Fig. 151. (After Marlatt, Bull. Bur. Ent., U. S. Dep. Ag.)

cases the character of the food may be determined from the mouth structure. The more primitive form is the simple mandibulate organ with maxillæ or accessory jaws, and insects of this type may grasp or cut or chew the food, swallowing solid food material, or in some of the predaceous forms suck the juice from the animals which they capture. The other principal type of mouth consists of a suctorial organ which is formed by modification of the mandibles and maxillæ or parts of the labium. The proboscis, or sucking organ, of bugs, flies, butterflies, and bees illustrates this modification. In all these forms food must be taken in the liquid form only. It may be noted that a recognition

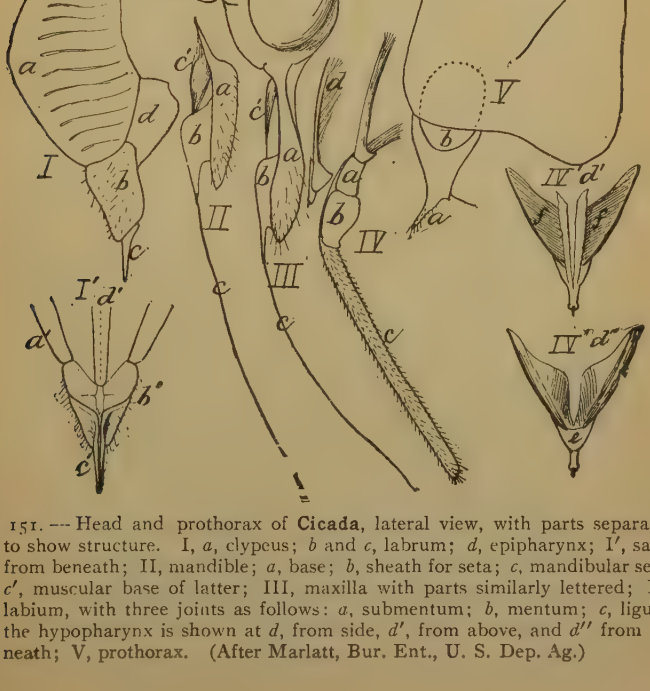


FIG. 151. — Head and prothorax of **Cicada**, lateral view, with parts separated to show structure. I, *a*, clypeus; *b* and *c*, labrum; *d*, epipharynx; I′, same from beneath; II, mandible; *a*, base; *b*, sheath for seta; *c*, mandibular seta; *c′*, muscular base of latter; III, maxilla with parts similarly lettered; IV, labium, with three joints as follows: *a*, submentum; *b*, mentum; *c*, ligula; the hypopharynx is shown at *d*, from side, *d′*, from above, and *d″* from beneath; V, prothorax. (After Marlatt, Bur. Ent., U. S. Dep. Ag.)

of this difference in taking food furnishes a basis for two main lines of treatment, the biting insects, as a rule, being most easily killed by poisons distributed on the surface of foliage, while the sucking insects cannot be reached in this manner, but must be killed by contact poisons, oils, resins, lime, sulphur, etc.

The legs, while modified in size with reference to mode of locomotion and in a few instances with some parts aborted, are in the main very constant in their general structure. The three pairs are present in practically all existing insects, and the modifications lie particularly in the tarsal segments, which, primitively five in number, may be reduced to four, three, two, or even one. The pulvillus, however, is quite variously modified in different groups and termed **empodium**, **arolia**, etc., in some orders.

The wings, ordinarily four in number, are membranous expansions of the body wall, and are supported by stout thickenings or rib-like portions termed **nerves** or **veins**, and the arrangement of these throughout the wings is spoken of as **neuration** or **venation**. Wings are greatly modified in different groups of insects, in some cases both pairs being thin and transparent, as in the dragon fly. The front pair may be thickened or leathery, as in the grasshoppers, or still more thickened, forming a hard horny case, as in beetles, or partly leathery and partly membranous, as in bugs (*Hemiptera*); they may be broad and covered with minute scales, as in butterflies and moths, or the number may be reduced to two, as in flies and mosquitoes, and the hind pairs may be aborted or modified into special organs called **balancers** or **halteres**. The degree of development in these locomotor organs is of particular importance from an economic standpoint, since the ability of the insect to fly to greater or less distances determines very directly the extent of its migrations, and the means by which it may be controlled. The fact that the female of the canker worm moth is wingless is of direct economic importance, as it can be seen at once that the dispersal of the insect must be very limited, as compared with insects that fly readily, and, moreover, that the necessity for it to ascend a tree for the deposition of

eggs makes possible certain measures of control. Again, the entire lack of extended locomotion, either by wings or legs, in scale insects is at the foundation of every rational mode of control of these destructive forms.

There is a very interesting question as to the origin of wings of insects, as these organs are distinctly different in their structure from organs of locomotion in any other group of animals. While functionally like the wings of birds and bats, their structure is totally different. They appear, as shown by the record of fossils, very much earlier than organs of flight in any other group of animals, and so far as we can determine by their structure, they must have had a very distinct mode of origin. Apparently they must have arisen for some other function than flight, and since they contain branches of the tracheal system, it seems probable that they arose first as organs of respiration in water and were then later modified into organs of flight.

The abdomen, or third region of the body, is composed of about nine or ten visible segments that do not bear any segmented appendages, but the terminal segments are modified or included with the reproductive organs. The first seven or eight segments have on either side small openings (spiracles) into the tracheal system, and there are also usually two spiracles located on the thorax. They are so small as to be scarcely visible without magnification. They are connected internally with the delicate respiratory tubes, the tracheæ, which extend throughout the body so that the air is distributed to all of the tissues, and the respiratory process is consequently carried on in all parts of the body. The minuteness of the spiracles makes it possible for the insect to be suffocated by a very small amount of oily material spread over them.

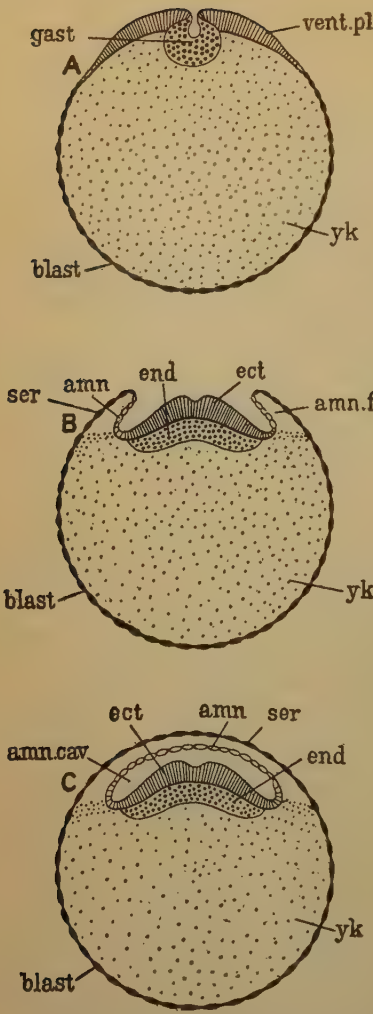
Aside from modifications of the alimentary canal connected with differences in the food, there are some special contrivances connected with the method of ingestion, such as the development of pumping organs as a part of the pharynx or crop. Such special pumping organs occur in the bugs, flies, butterflies, moths,

ants, wasps and bees. The essential feature is the arrangement of muscles for the distention of the canal so as to form a vacuum behind the proboscis. The fluid food, however, in some cases, doubtless moves into the proboscis tube by capillary attraction, and is drawn from the mouth into the canal by suction of the pumping organ. Salivary glands are usually well developed, extending back into the thoracic region. The gastric glands differ in development, but cæca such as appear in the grasshopper occur in many different groups. The excretory organs, Malpighian tubules, are much varied, the more primitive form consisting of a small number, two to six excretory tubes opening into the posterior part of the intestine; but in many cases the tubes are greatly increased in number, in the grasshopper, for instance, reaching something like one hundred and fifty, branching from one stem. The circulatory vessel varies in width and consists of a series of pulsating chambers, these frequently expanding in the abdominal region, and the blood vessel narrowing anteriorly, the current of colorless blood being driven forward. The nervous system is very uniform in general pattern, but the number of ganglia varies from the more primitive condition, where there are numerous ganglia corresponding to the segments, to the more specialized forms, where the thoracic ganglia are fused into one mass, the abdominal ganglia reduced in number and partially fused, while the cerebral ganglia are much enlarged. The enlargement of ganglionic masses in the head region is termed cephalization, and is connected with a higher degree of nervous activity, and doubtless much greater efficiency of sense organs. Such a specialized condition is found in the house fly, ants, bees, and wasps.

The special senses of the insect are undoubtedly well developed, but in many cases it is difficult to determine their location. We know with certainty that the compound eyes and ocelli are organs of vision, since their structure and location indicate this, while additional proof, furnished by their response to visual stimuli, proves it experimentally. The character of the vision,

however, is not so evident, and certainly we may doubt whether insects recognize images such as are formed in the human eye. The immense number of facets in the compound eye, if representing individual images, would form an extensive complex which would seem to be of slight use for seeing images, but if stimulated by movement of some object, their structure would seem to provide for ready recognition and location of such movement. This would be effective either in case the insect were still and the object moving near it, or if the object were still and the insect on the wing were in motion. The fact that dragon flies and some other predaceous insects capture insects on the wing with great dexterity certainly proves an exact location of objects. Hearing is indicated by the fact that many forms produce sounds, and these sounds in many species form the basis of recognition between the sexes. The auditory organ, however, varies greatly in position and structure. The tympanic membrane on the basal segment of the abdomen of grasshoppers, similar tympanic structures at the base of the prothoracic fore tibiæ in crickets and katydids, and pitlike structures or vibratile hairs on the antennæ, are among the organs to which hearing is referred. The male mosquito, for instance, has delicate hairs upon the antennæ which vibrate in unison with the song of the female, and it is asserted that the direction of the sound can be determined within a range of five degrees. Organs of smell are located on antennæ and palpi, possibly on other organs, while taste is located in nerve endings of mouth parts, the most specialized perhaps being located in the epipharynx. Tactile papillæ or tactile hairs occur on different parts of the body, but particularly on antennæ and palpi.

The reproductive organs in insects show great variety of structure, adapting them to different conditions of life, and especially to different modes of oviposition. The simpler type perhaps is a saw-like organ for forcing eggs into the tissues of plants or under the surface of the ground, and the tubular telescopic form, a more specialized though apparently simpler type. The eggs are of almost infinite variety of form, and are deposited in a great variety



of locations according to the habit of the species; and there are some instances where reproduction takes place viviparously. Parthenogenesis in aphids consists of the production of a number of generations without the appearance of normal males and females, all young produced during these generations developing without the fertilization of ova; while in the case of the honey bee, unfertilized eggs develop into males, the fertilized eggs into workers or queens. Eggs may be produced in enormous numbers, the queen honey bee producing hundreds of thousands each season, some millions probably in a lifetime of three to five years, while on the other hand, in some instances, eggs are limited to two or three or a very few in number. In most species multiplication is very rapid, but offset by

FIG. 152. — A–C, transverse sections through the developing ovum of an insect at successive stages to show the mode of development of the germinal layers and of the amnion. *amn*, amnion; *amn.f*, fold of the amnion; *amn.cav*, cavity of the amnion; *blast*, blastoderm, covering the yolk; *ect*, ectoderm; *end*, endoderm; *gast*, invagination of ventral plate; *ser*, serosa; *vent.pl*, ventral plate; *yk*, yolk. (After Korschelt and Heider.)

enormous loss of life, so that under ordinary conditions the number of individuals in a species remains fairly constant from year to year.

A few insects are developed directly from egg to adult form without any striking change; others in successive stages of growth or at molting periods change slightly in form and ultimately acquire wings (incomplete metamorphosis), while the most specialized condition is found where there is a very complete and striking change, the egg hatching into an active feeding stage, the **larva**, which may molt several times with increase of size and then change to a quiescent form, the **pupa**, differing totally from the larva, and this in turn giving rise to another totally different stage, the mature active winged condition, **imago**, in which reproduction occurs. The striking changes in these latter forms make the tracing of the cycle from one stage to another a most fascinating study, as it is necessary to actually rear the insect through different stages in order to determine the different forms which belong to the same species. It may be remarked that the different stages of larva and pupa have apparently diverged, in some cases very far, from the primitive form, having become adapted to particular environment, so that they do not stand in any sense as representatives of the line of evolution for their species.

The insects illustrate many different phases of life, and it is possible to study almost every phase of animal activity within the group. In their flight they show one of the most striking adaptations among the invertebrates, and in a way parallel or even surpass the group of birds, which is the dominant form of aerial life among the vertebrates. Undoubtedly the power of flight has been a main factor in the enormous development of the group and its successful adaptation to the most diverse conditions. In some instances we have apparently migration similar to that of birds, the monarch butterfly, for example, being known to travel southward in autumn and northward in spring. Insects are, also, transported to great distances by various agencies, such as

attachment to birds, action of wind, currents of water, and especially by human agencies, many species having been distributed by movements of commerce to all quarters of the earth.

In the aquatic life of insects we see a very great diversity of adaptation, nearly all forms, however, retaining tracheal respiration in some form or other. In some cases, as in larval dragon flies and stone flies, the spiracles are closed and the air within the tracheal tubes oxygenated by contact of water with delicate tracheal gills which may be external expansions of the body, or, in some dragon fly larvæ, located within the rectum, where water currents passing in and out serve not only for respiration but for locomotion. In many forms the tracheal system remains open and the insect must rise to the surface of the water at frequent intervals to replenish its supply of oxygen in the tracheal system. Larvæ of mosquitoes and water beetles, water bugs, some of the larval flies, etc., illustrate this necessity, while in a rather extreme case, the buffalo gnat larva, there are blood gills through which flow of body fluid provides for taking up of oxygen. These blood gills, however, have recently been shown to be specialized from tracheal gills, the tracheal tubes being reduced.

In the matter of social life insects show some very striking instances, some of which present striking parallelisms to human society. The more primitive condition is certainly that of normal male and female insects providing for succeeding generations by deposition of eggs which hatch and produce larvæ which, without any attention from the adult forms, — adults in fact usually dying as soon as eggs are laid, — must provide for themselves during all stages of growth. Some forms, again, are gregarious, large numbers clustering or feeding together, and in some cases inclosing themselves in dense webs so that they gain protection. The white ants live in colonies including great numbers of individuals and showing much division of labor. There are commonly an egg-laying queen, numerous winged males at certain seasons, and then large numbers of neuters which may assume the form of workers and of soldiers, having different capacities and very

different and definite functions to perform in the colony. These, while widely separated from the true ants and having their community life developed entirely independently, show marked similarities, and indicate that similar conditions of community life result in the production of very similar types of members in the community. Community life of ants results in a great variety of neuter forms, mentioned more fully in connection with discussion of the family, while in the wasps and bees somewhat different phases of community life appear. Here, again, the development of the community appears quite independently of its existence in other groups; that is, we may trace an entirely distinct series of adaptations to community existence in the white ants, a culmination of which appears in such forms as the termites of Africa; the true ants which show gradations from quite simple colonies, consisting of but few individuals and with no continuity of community life, to forms which have a very complex series of neuter forms, providing for very diverse activities in the colony; the wasps, which start with solitary forms and develop along steps of complexity up to the paper-making hornets, in which a large colony develops during a season, but which is not carried over to following years; and the bees, again, which show a series from a simple wild form, with no neuters and with no continuity of community life, to the bumble bees, where a simple community exists during a part of the year only, and finally the honey bee, in which community life becomes continuous, provision by swarming serving to perpetuate the colony indefinitely. In the white ants and true ants, neuter forms are wingless, but this condition has not developed in any of the wasps or bees. The care of the young in these communities differs greatly, but in practically all forms includes some method of provision for the young, food being supplied in all cases so that the young may develop without any exposure to external conditions. The communities include other insects, in the capacity of guests or parasites, these sometimes obtaining shelter only, sometimes food without detriment to the host colony, but in many cases living at the expense of the host. In

some instances the parasitic forms have assumed the shape and appearance of the host insect, which appears to permit their more ready entrance to the colony. In some cases they seem to be simply tolerated, in other cases apparently welcomed. The architecture has been developed in many forms to a high degree of perfection, the immense mounds of African termites, the extensive galleries and mounds of the common ants, the mud and paper nests of wasps, the wax cells constructed by bumble bees, and the more perfect comb of the honey bee, being examples. Among the ants we have also a peculiar phase of community habit in the slave making, which consists of the capture and retention of ants of other species and their utilization in the duties of the colony.

Phosphorescence occurs in a considerable number of insects, evidently developed independently in members of quite different orders and families, sometimes in the larval stages and sometimes in adults. The lantern fly, *Fulgora*, of southern Asia, is reputed to give off a distinct light from large areas on the greatly expanded head. The larvæ of certain click beetles are strongly phosphorescent, the phosphorescent points being distributed along the sides of the body, while in a tropical click beetle the adult has large phosphorescent spots on the prothorax. Our common fireflies or lightning bugs, belonging to the family Lampyridæ, are beetles with the phosphorescence present in the abdominal segments of the adults. In these the light is intermittent, apparently controlled by impulses of the nervous system. In all cases phosphorescence appears to be due to the sudden oxidizing of certain tissues, probably specialized muscle fibers, and the nerve impulses serving to liberate at intervals an excess of the substance, which combines with the oxygen to produce the more brilliant effects.

Insects bear a considerable number of special organs or structures not common to other groups. Wax glands, developed from dermo-cutaneous glands, produce waxy secretions or coverings in scale insects, cottony fibers in certain aphids, the lac of lac in-

sects, and wax of the honey bee. The scent glands of Hemiptera produce striking odors such as are given off by the bedbug, chinch bug, stink bug, etc., and the scent organs of moths furnish odors by which the males are attracted for long distances to females. These latter may be counted attractive, while the former, possibly attractive within the species, serve also as defensive or repugnatorial organs. Silk glands are developed in many forms but culminate in spinning moths, silkworms, and related forms. Organs of adhesion are found not only in the claws, but in specialized structures on the tarsi, such as the empodia of flies, which provide for adhesion to smooth surfaces, enabling a fly to walk up a vertical pane of glass or adhere to the ceiling. The empodia in this case are provided with numerous **tenent** hairs which exude a thin mucilaginous fluid, a minute quantity of which at the tip of each hair serves to hold the insect.

Losses from injurious insects are very great, and many of them could be greatly reduced by adoption of measures of control now well known. It is estimated that insect injuries amount to at least one tenth of the average crop annually, which would be something like six or seven hundred millions of dollars for the United States during each of the past few years (1905 to 1907). All the various kinds of crops and crops in all stages of growth pay their tribute. Cereals suffer from the time the seed is planted till the harvested grain is stored, or even after mill products have been distributed to dealers and consumers. Fruits suffer in root, stem or trunk, branch, bud, leaf, and fruit. Domestic animals are annoyed, preyed upon, or their substance consumed, and both domestic animals and man are subject to inoculation with deadly diseases through the agency of insect pests. These losses are distinctly an economic waste, and like losses from fire and flood present little in the way of compensating advantage. Even if the increased price for a depleted crop helps one section at expense of another, the total result is a loss to the community at large.

For very many of these insect pests there are now definite

measures of control, but as yet only a very small proportion of the people most vitally interested take the trouble to inform themselves as to these measures or to put them into use.

The useful phases of insect life must not be overlooked, however, and these are manifold. Some are predaceous or parasitic and serve to hold in check the destructive forms. Many have a most important function in the pollination of the flowers of important crop plants; and some produce important commercial products, among which are silk, honey, beeswax, cochineal, lac, cantharides, etc. Some furnish food material or are used as food among certain people.

Classification. — The classification of insects is particularly complicated on account of the enormous number of forms, the described species being estimated at the present time to be more than three hundred thousand. The complexity of structure and the many organs also serve to complicate matters, although in many instances furnishing excellent groundwork for the separation of groups. The wings, mouth parts, antennæ, legs, and genitalia offer particularly useful structures for classification. A first general division may be made on the basis of the presence or absence of wings, provided we recognize the difference between forms which are primitively wingless and those in which wings have been reduced or lost in species belonging to groups which show ancestral winged forms. Some of the divisions are very well marked and easily recognized. In other cases the distinction between groups is much less obvious. A very brief summary of the common groups with mention of well-known examples may properly precede the more detailed statement of the orders.

The **Thysanura** (or **Apterygota**) include forms which are recognized as primitively wingless, that is, as having no trace of wing structure or any affinity to ancestral winged form. The bristle tails and spring tails are included here. The remaining orders of insects (**Pterygota**) all have wing structures or show their derivation from winged forms. *Ephemeridæ* are delicate frail forms with aquatic larvæ, the adults with rudimentary mouth

parts. Our common May flies are included here. The *Odonata*, strong-flying, slender-bodied insects with very large compound eyes, are known as dragon flies. The *Orthoptera*, including cockroaches, grasshoppers, katydids, and crickets, have biting mouth parts, the front wings usually somewhat thickened, and the species are all terrestrial. The stone flies, *Plecoptera*, are aquatic in larval stages, have biting mouth parts, the hind wings folded in broad plates. The *Isoptera* include the white ants or termites, which have finely net-veined wings and live in colonies. Of the *Corrodentia* the book lice are wingless, but there are related forms which are winged, while the *Mallophaga*, or parasitic biting lice, are entirely wingless.

The *Thysanoptera* are minute fringe-winged forms known as thrips. The *Hemiptera* have suctorial mouth parts, the group including the cicadas, tree hoppers, leaf hoppers, plant lice, scale insects, bugs, etc. All of the preceding orders are developed without marked transformation, and are spoken of as having incomplete metamorphosis.

The order *Neuroptera* has complete metamorphosis, biting mouth parts, and densely net-veined wings, the group including the hellgramite fly, lace-wing flies, ant lions, etc. The *Mecoptera*, or scorpion flies, have a prolonged head with small jaws at the end, the males with a swollen terminal abdominal segment resembling the stinging segments of a scorpion.

The *Trichoptera*, or caddice flies, have biting mouth parts, the body scaled or hairy, the larvæ aquatic. The *Lepidoptera*, including moths and butterflies, is one of the most striking groups of insects, and is distinguished by scaly wings and a suctorial mouth. The *Coleoptera*, or beetles, with hard wing covers, and strong biting mouth parts, are among the largest and most distinctively marked orders. The order *Diptera* is particularly well marked on account of the single pair of wings, and includes hosts of well-known forms, such as house flies, mosquitoes, gnats, etc. The *Siphonaptera* are wingless, semi-parasitic forms related to flies. The *Hymenoptera*, ants, bees, wasps, and saw flies, are specialized,

many families including species having a highly organized community life.

Of these orders, the *Orthoptera*, *Hemiptera*, *Lepidoptera*, *Coleoptera*, *Diptera*, and *Hymenoptera* are especially important, including among the large number of species many destructive forms, some of which will be discussed more fully in their proper place.

Review of the Orders

Order Thysanura. — These are wingless insects with no trace of rudimentary wings and evidently without any winged form in their ancestral series. They are commonly covered with minute scales, the mouth parts mandibulate, the antennæ simple, being either slender bristles or short and with few joints. At the end of the abdomen there are three long slender bristles (Thysanura proper) or a specialized forked structure bent under the body which serves as a leaping organ (spring tails or Collembola). These latter forms are for the most part feeders upon decaying vegetable matter. They are found in moist places, and some species even live on the surface or under water. Very few of them have economic importance. Some of the bristle tails live in houses and by feeding upon starchy materials, infesting pantries and attacking draperies which are starched, may cause considerable injury.

Fig. 153. — **Lepisma saccharina.** Silver fish, adult, enlarged. (Howard and Marlatt, Bull. Div. Ent., U. S. Dep. Ag.)

Order Orthoptera. — This order contains some rather distinctly specialized groups, but at the same time combines rather primi-

tive characteristics; and since one of the families, *Blattidæ*, containing the cockroach, appears to be one of the most abundantly represented groups in early geological times, it may be looked upon as one of the most primitive groups of winged insects. The wings are usually flattened and lie flat upon the back, the front pair often somewhat thickened and the hind pair at rest commonly folding fanlike underneath the front wings. The mouth parts are

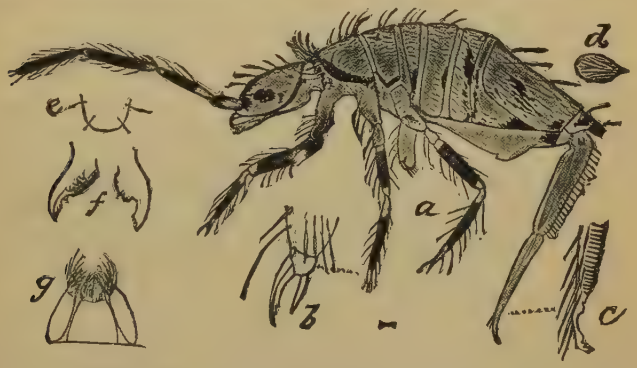


FIG. 154. — **Lepidocyrtus americana**, spring tail. *a*, lateral view of female; *b*, foot of same; *c*, tip of spring tail; *d*, body scale; *e*, upper lip of labium; *f*, mandible; *g*, maxilla and labium. (Howard and Marlatt, Bull. Div. Ent., U. S. Dep. Ag.)

always mandibulate, the legs adapted for running, or in the grasshoppers for leaping, the hind legs being greatly enlarged. The order includes several families, the Cockroaches (*Blattidæ*) being perhaps the most primitive, the walking sticks and leaf insects (*Phasmidæ*) containing some remarkable cases of protective resemblance or mimicry, the mantids including predaceous forms, the common praying mantis being a familiar form south of the latitude of Washington. The grasshoppers (*Acrididæ*) are numerous in species, and many of them extremely destructive, among them the Old World locusts, whose migrations and devastations have been noted from antiquity. The Rocky Mountain grasshopper, which during the period between 1875 and 1880 devastated a large territory in the upper Mississippi Valley and prairie region,

and our common red-legged grasshoppers, which are a constant and serious source of loss in grass land all through the eastern United States, are striking examples. The annual losses from our common species must be very great but difficult to estimate exactly, because in their attacks upon grasses they mow down and devour large quantities without killing the plants, so that their destruction is largely unnoticed. The differential grasshopper, already described, is another very widely distributed and destructive species. An interesting species showing distinct protective coloration is the beach grasshopper common on sandy beaches.

FIG. 155. — Beach grasshopper, **Trimerotropis maritima**, showing protective resemblance in color and marking like sand grains. (From drawing by D. D. Shira.)

Order Euplexoptera. — THE EARWIGS. We have here a little group related to and sometimes included in the Orthoptera. It includes forms which have well-developed wings, with a special venation. The veins are generally large, with a number of cross veins. The wings are folded like a narrow fan and are covered or protected by the small forewing. This is leathery, hardened as in case of beetles, opaque, or in some cases more transparent. They have biting mouth parts and incomplete metamorphosis. They have forceps-like structures at the end of the body.

Order Plecoptera. — This order, including the common stone flies, is quite similar to the Orthoptera in many general characteristics, but the hind wings, which are very broad, are folded in plates under the narrow front wings. The front wings are quite densely veined and often quite opaque; the larval stages are aquatic

and possess striking respiratory organs in the form of tracheal gills adapting them to the aquatic life. The species are much less numerous than in most of the other orders, and, except as they constitute a source of food supply for fishes and other aquatic animals, have little economic importance.

Order Ephemerida. — The May flies are interesting forms and have become especially well known on account of the enormous numbers which appear at times, especially in the vicinity of fresh water. The extreme brevity of life pertains only to the adult stage. The larvæ are aquatic and require one, two, or in some cases three years for the completion of their growth, but on issuing and attaining adult life their survival is for but a few hours, or, at most, a few days. On issuing from the water they assume a winged stage, which, however, is still immature, termed the "pseudimago," which flies and finds some suitable place of attachment, rests for a time, and molts to assume the adult stage. Mating occurs on the wing, and immediately after the females deposit eggs on the surface of water. They then die, and since their bodies are extremely frail, all traces of them are soon lost. These May flies appear in millions along the shores of lakes or streams, and, attracted by lights, they will accumulate in enormous quantities around electric lights, street lamps, and brilliantly lighted buildings.

Order Isoptera. — This group includes white ants, or termites. It is an important group, occurring in many countries and often a great pest. They are rather specialized, live in colonies in large nests built in mounds or in old logs and stumps, a characteristic which has led to the development of different classes, much as in the ants and bees. They have biting mouth parts, which in the soldiers and workers are very strong, but not so strong in the females and males. The wings are nearly equal in length and lie flat on the back, are finely net-veined and whitish transparent in appearance. The bodies of the females are brownish, the bodies of the workers are whitish with brownish heads, and the females when gorged with eggs have transparent body walls.

The males and females correspond most nearly to the primitive form, but are modified and specialized, and do little, if any, of the work of the colony. In general, a new colony is started by a female which has issued from a colony and been fertilized in flight,

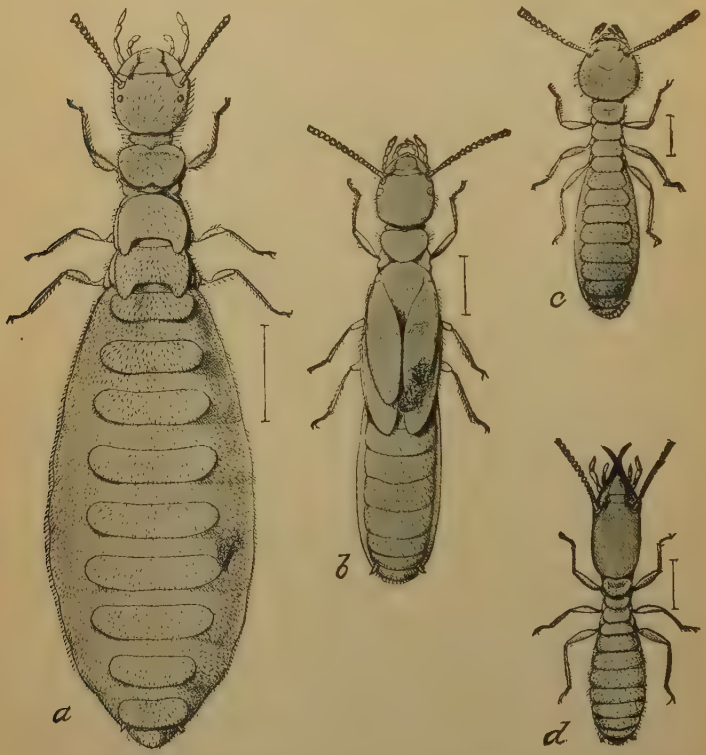


FIG. 156. — **Leucotermes flavipes**. *a*, queen; *b*, nymph of winged female; *c*, worker; *d*, soldier. All enlarged. (Howard and Marlatt, Bull. Div. Ent., U. S. Dep. Ag.)

being captured by a number of workers and established in a favorable location. The workers carry on all ordinary work of the colony and provide food. There is a division of labor and development of polymorphic forms as in the Hymenoptera, but there

FIG. 157. — Block of chestnut wood showing excavations of the white ant, **Leuco termes flavipes**. (From photograph by H. T. Osborn.)

is no affinity between these groups, and the community condition must have developed independently. Slavery with the white ants seems not to have been taken up. The colony is composed of female "queen," supplementary queen, male "king," sub-queens, supplementary males, workers and soldiers which are neuters representing both sexes, so there may be some eight different forms in the colony.

Their natural food is woody fiber; they enter timber of almost any kind, first making long chambers through it, then consuming a large part of it. Because they work on the inside of the wood they are not recognized and may do a great deal of damage before they are discovered. Staircases, bridge trestles, and other structures are rendered insecure by them. They are more numerous in tropical countries, and steel ties are used in many places for the railroads instead of wood. Stone, tile, and earth floors are also used to a great extent to avoid their damage. They build covered ways under which to travel when they have to cross a stone foundation or open space above ground, for they cannot endure the strong light. Africa, India, and Australia are especially noted for their abundance, and houses are often overrun with them. Furniture and all wooden articles may suffer.

The species occurring in the United States is *Leucotermes flavipes*. Aside from attacks on wooden structures, they feed on paper and books and have occasioned losses in the Capitol at Boston by feeding on old documents and records, and caused considerable damage also in the Capitol at Springfield, Illinois. In libraries located so as to be exposed care should be taken to exclude them and to keep the books on steel and not wooden shelves. Cement or tile floors and other precautions may be used. They construct burrows under ground, but the nest usually occurs in the trunks of fallen trees or in stumps. One phase of injury noted in Southern States is the attack upon fences. They are said to be more likely to attack boards and posts when covered by up-and-down pieces.

Order Corrodentia. — Somewhat related to Isoptera, we have a

small group Corrodentia, which includes book lice, mostly included in the family Psocidæ. The most common form of book

FIG. 158. — **Atropos divinatoria.** *a*, adult from below; *b*, same from above; *f*, maxillary palpus; *e*, maxilla (?); *d*, mandible; *c*, labium. All enlarged. (Howard and Marlatt, Bull. Div. Ent., U. S. Dep. Ag.)

louse is *Atropos divinatoria;* they are wingless and feed on starchy materials of different kinds. They work inconspicuously in books and are more active in corroding the surface and scraping off the

lettering than in destruction of paper. Those species that live on trees feed on lichens, travel in herds, and many of these tree-inhabiting forms are provided with wings when mature.

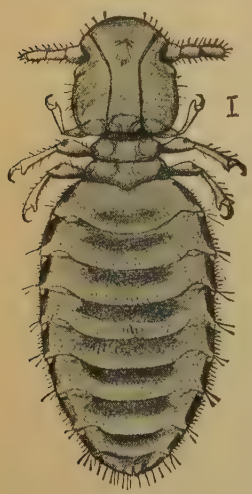


FIG. 159. — **Trichodectes parumpilosus.** Enlarged. (Author's illustration, Bull. Div. Ent., U. S. Dep. Ag.)

Order Mallophaga. — These live as parasites on birds, among the feathers, or in hair of mammals. They do not feed on living tissues. Some authors have gone so far as to say that they are beneficial as cleaners. They are irritating by their creeping, and the irritation is sufficient to cause the animal much annoyance and is no doubt detrimental to it. They are wingless and have biting mouth parts. Some forms show close relation to Psocidæ, and the group seems to be derived from a similar stock. Some live on birds and some on mammals. They cannot survive long off their host, and in the majority of cases they are adapted to a particular kind of host. There are species that occur on the dog, cat, cattle, etc. There appears to be a special tendency to migrate from older to younger individuals. Some possess specialized clasping and clinging structures. There is one species found on the pelican which occurs in the gular pouch; its body is elongated and it seems possible that it will in time become wormlike, possibly resembling the tapeworm, if this habit goes on. The species that occur on horses and cattle are the best known to

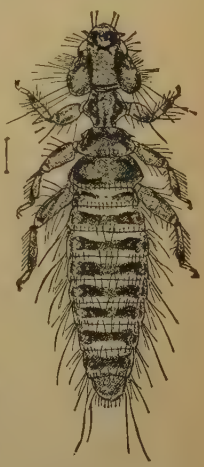


FIG. 160. — **Trinoton luridum.** Enlarged. (Author's illustration, Bull. Div. Ent., U. S. Dep. Ag.)

stock raisers. They may be killed by kerosene washes or by fumigation.

Order Odonata. — The dragon flies are a conspicuous group, distinguished by their large heads, prominent eyes, strong mandibles, densely net-veined nearly equal wings, and slender abdomens. The larvæ are aquatic, carnivorous, and have a peculiar adaptation of the labium which enables it to be thrust forward for the capture of prey. They are supposed to feed quite extensively on mosquito larvæ, and as the adults also prey upon mosquitoes, they are to be reckoned among the useful checks for that pest.

The eggs are laid at the surface or beneath the water, the adults in some species creeping down the stems of plants to a depth of several inches to attach the eggs. Others simply skim over the surface, dropping eggs into the water, where they scatter indiscriminately. Most species are supposed to complete the cycle of development in one year.

Libellula pulchella, a common North American species, is distributed over eastern United States, and very frequently may be seen darting around in meadows or pastures or resting on bushes near water. Its method of capturing insects on the wing and its deposition of eggs may be observed with a little patience. Its larva is a broad-bodied, rather flattened species, and if observed under water, may be seen to draw in and force out currents of water through the anal opening. These water currents serve to bathe delicate tracheal gills which line the walls of the rectum and in this way provides for its respiration. The sudden ejection of the water serves also as a means of movement, the insect being thrown forward to a distance of two or three inches.

Order Thysanoptera. — The species in this order are all very small and have the mouth parts intermediate between the biting mouth parts of the Orthoptera and the suctorial mouth parts of the Hemiptera. In some respects they may be considered as intermediate between these two orders, but not as a distinctive connecting link, because in the matter of wings they have a specialization of their own. They are minute, all very small, the

largest not over one eighth to one fourth of an inch in length, Many are less than one sixteenth of an inch. They have very slender bodies and slip around readily between the parts of the blossoms of many different kinds of plants. The different stages occur in the bloom of different kinds of plants, and they feed, at least in large part, upon the soft tissues of the parts of blossoms, puncturing and corroding this soft portion so as to secure the juicy contents. In some cases this results in preventing fertilization and consequently a loss of crop.

Order Hemiptera. — This is one of the large orders of insects and includes some very important economic species, and some of the very striking specializations in insect life history, including extremes in different kinds of environment, life habit, and one of the most striking extremes in the matter of reproduction and development. The essential character of the order is in the development of the mouth parts, there being pretty distinct differences in the matter of wing structure and some other parts of the body. The mouth parts (see Figs. 150–151, of cicada) are adapted for suction in the larval as well as the adult stages. This represents a more complete specialization than when the mouth parts are different in different stages. The modification in the mouth parts consists in the change of the mandibles and maxillæ into bristles or setæ which serve to puncture the tissues of the plants upon which the insects feed and to pump out the juices. The labrum is present as a rather aborted structure; the labium is modified into a sheath for the bristles or setæ and is usually three- or four-jointed. These are fitted together to form a sheath or tubular or furrowed organ within which the bristles or setæ play back and forth as they are driven into the tissues which constitute the food of the insects. Within the group there are differences in wing structure, which enable us to separate the group into two very distinct orders, and in some cases three are recognized, the third including only parasitic forms.

The two main suborders are the Homoptera and the Heteroptera, the first including those forms which have membranous or

opaque but homogeneous wings, the second having the front wings thickened at the base and membranous for the apical portion. The Heteroptera are often given first as if more primitive, but the Homoptera appear to have the most primitive character. The venation of the wings and the position of the head especially seem more primitive.

The third group, Parasita, includes the suctorial lice; the wings are lost, the beak single-jointed, the setæ are much elongated and tubular. They are restricted to the warm-blooded vertebrates, living on mammals only.

Of the Homoptera, one of the most widely known is the seventeen-year cicada, which is especially remarkable on account of its long life. The seventeen-year cycle is certainly known and well established by observation. The adults appear at these periodic intervals, in the latter part of June, and they are apparent during this stage when they feed very slightly on vegetation, mate, and deposit their eggs during a period of four or five weeks, though they are seen in great numbers for a period of only a few days. They are noticeable from their size and from the very loud note that is produced by the males. The song is a long-drawn-out sort of screech, and is produced by an organ located in the base of the abdomen, covered by the wings when folded and slightly covered from below by an operculum. The shape of

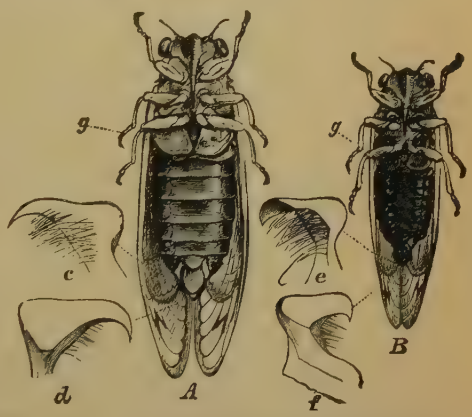


FIG. 161. — Seventeen-year cicada, **Tibicen septendecim.** *a*, male of typical form, natural size; *c*, *d*, genital hooks — enlarged; *g*, singing apparatus; B, male of smaller form, **cassini**, natural size; *e*, *f*, genital hooks — enlarged. (After Riley and Hagen.)

the drum is somewhat flattened, and inside is a cluster of muscles attached to the abdomen. Their contraction serves to draw this membrane in, after which it immediately resumes its former position. This causes very rapid vibration, producing a whirring or buzzing note which varies in intensity with the rapidity of the vibrations. Its purpose is presumably that of a mating call. The females deposit eggs in twigs of trees, puncturing the trees with little furrows which result in splitting the bark, and the twigs often die. The eggs hatch five or six weeks after their deposition. The larvæ pass into the ground and from that time on for the next almost seventeen years are out of sight and are growing gradually, molting occasionally. They feed for the most part on the roots of trees and shrubs and woody plants constant in their location. When trees are cut away after the eggs are deposited, some of the larvæ die, but occasionally there are some that become mature.

The uniformity in their appearance may be accounted for by the fact that those that did not come out at a definite time had little chance of breeding and reproducing. The molts have not been accurately determined for the whole period, but they molt about once a year. They occur throughout the eastern United States, and the seventeen-year form mostly to the north of the latitude of the Ohio River. To the south of that latitude there is a thirteen-year form. They do not occur over the whole area of the country in which they may be considered as native, there being portions where they do not occur at all, other places where they occur twice in seventeen years, and still other places where they occur three times in seventeen years. They may be descendants of a generalized mass of cicadas with a shorter life period. Just why they have been retarded is another problem. Their subterranean habit and consequent slow growth would prolong their life.

In the aphids most of the species have a very striking form of asexual development. Hibernation is in the form of normal eggs produced by sexual reproduction. They hatch in the spring into what is called the stem mother, and all the individuals hatched

from these eggs are capable of reproducing without fertilization, and each may give rise to a considerable number of young, and these again to other young by the same process, and this may go on for a long series of generations, ten or twelve in a season. The only particular variation occurs a few generations after the first start in spring, when there is very commonly a generation of

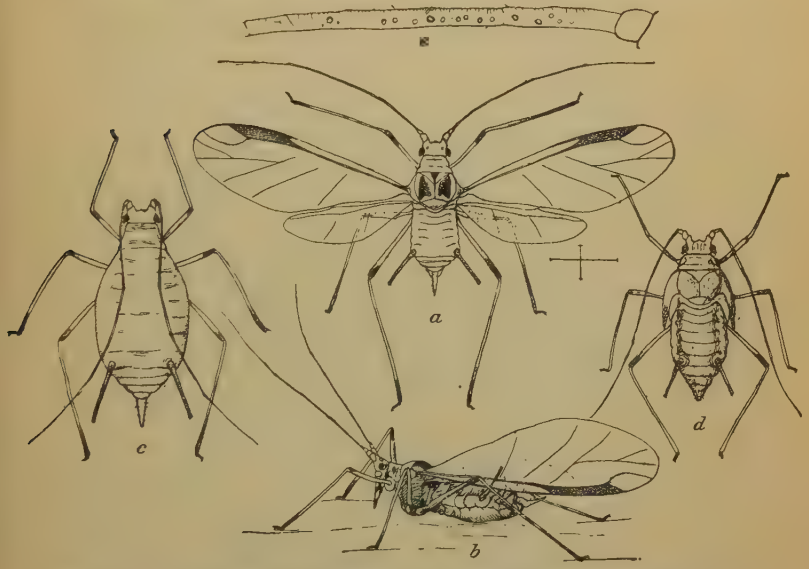


FIG. 162. — Aphid, **Nectarophora pisi**. *a*, winged female; *b*, same from side, wings folded; *c*, apterous female; *d*, nymph in last stage; *e*, third segment of antenna, winged form. *a–d* much enlarged, *e* still more enlarged. (From Div. Ent., U. S. Dep. Ag.)

winged individuals, though most of the sexual generations are wingless. That provides a means of dispersal for colonies that have become enormously abundant. There is also very commonly an alternation of food plants. The migratory generation goes to a different host plant. In such cases there is a return migration in the autumn before the hibernating generation is produced. This would mean a second winged generation. Finally,

as a normal cycle in the autumn, a generation is produced which includes males and females, commonly wingless and very minute, and these mate and the fertilized females produce the winter eggs, which are very few in number for each female. These eggs are attached to twigs on the plants where the insects occur and where they will be more or less protected during the winter. They are produced as normal fertilized eggs by normal sexed individuals. This method of reproduction is somewhat paralleled in certain other groups of insects, but is not homologous. It provides for an enormous increase in number of individuals in insects exposed to unfavorable conditions. There are distinct specializations in the matter of habitat, etc., as well as in structure.

The relation of aphids to ants is another feature in their life which is of great interest and in which they show some most remarkable adaptations. The basis of this association is to be found in the secretion from the aphids of a sweetish fluid called honey dew which the ants have apparently learned to use as a food and of which they seem very fond. In its simplest condition this association consists only in the visits of ants to individual aphids or to colonies in their ordinary location on the leaves or twigs of plants. In such cases numbers of ants may be seen passing back and forth from their nests to the aphid colony. An improvement on this plan is evident in some forms where the aphids are given a certain amount of protection, other insects are excluded, so that the ants themselves may have the full benefit of the protected insects. This is accomplished by the building of an earthen covering up around the stem of the plant on which aphids are present. This, of course, occurs only upon low-growing plants such as strawberries or vines trailing upon the ground. Still other forms go farther and colonize the plant lice upon roots of plants convenient to the ant nest so that they will be readily accessible for the purpose of furnishing food. It is claimed even that some species of ants will carry the eggs of aphids into their nests, keep them over winter, and in spring transfer them to their proper food plant so as to make sure of a colony for the season.

This method, while difficult to verify, is perhaps hardly more intricate than other combinations amongst insects. It has been most definitely shown that for aphids living underground, as, for instance, in the corn root lice, the aphid has become absolutely dependent upon the ant for its success in reaching plant roots upon which it may survive. Indeed, this is so fully the case

FIG. 163. — Peach orchard showing destructiveness of the San José scale. Note the dead branches in lower part of trees. (From photograph taken at Put-in Bay by the author.)

that the most successful measure in controlling the species is to adapt cultivation of the soil to the constant breaking up of nests of ants and the interference of their transfers of the plant lice. On the other hand, we may infer quite certainly that the ants are quite dependent upon the aphids for their food supply, and that for the species which have become especially adapted to this food, the cutting off of their supply would greatly incon-

venience them and possibly result in their diminution or their extinction.

It will be recognized at once, on account of the enormous rate of multiplication in aphids and the fact that they occur on almost every kind of plant, that they constitute a very important menace to crops, and we have among them some of our most destructive species. Were it not for the enormous number of insect enemies, their great susceptibility to climatic changes, and a certain limitation in food supply so long as they remain in the unwinged form, they would certainly be among the most difficult of insects to contend with.

The San José scale, *Aspidiotus perniciosus*, is an introduced species which has been the source of an immense amount of loss in orchards, nurseries, etc. It presents some modifications from the ordinary form. It is small, with an almost perfectly circular scale. Exuviæ remain near the center, giving it a somewhat nipple-shaped appearance. When abundant they give a very scurfy incrusted appearance to the twig on which they occur. The male scales are similar but a little more oval in shape. The life history differs from most of the other species in that young are produced alive; some observers think, parthenogenetically. The eggs hatch before extrusion, develop rapidly, and mature in a short time. There may be as high as four, five, or six generations in a season. It has been estimated that a single female may be the parent of about three and a half billions in a single season. These being brought forth alive must have constant nutrition, and unless the scale has living tissue the insects must perish, though mature females might assume a dormant condition during cold weather. The only means of transportation appears to be upon living plant tissue. It is possible, therefore, to adopt restrictive measures, quarantine, inspection, etc. It is the most important species of scale known in this part of the world at the present time. It is now commonly treated with a lime-sulphur wash.

The Heteroptera include also a large assemblage of important species. Among them the bedbug, squash bug, cabbage bug, etc.

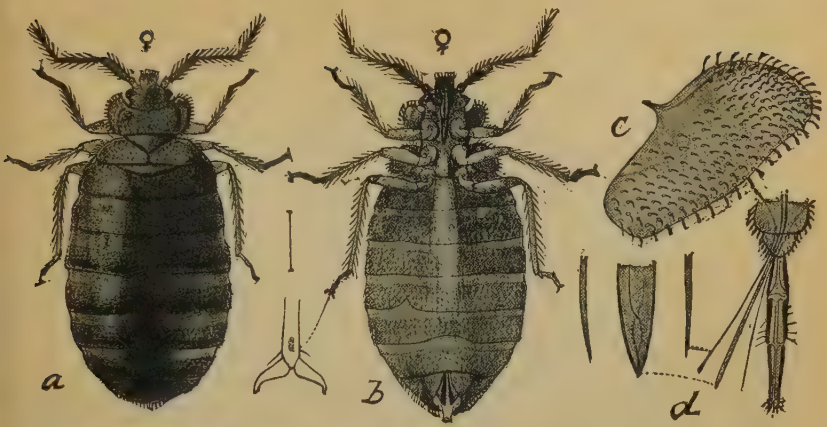


FIG. 164. — **Cimex lectularius.** *a*, adult female, gorged with blood; *b*, same, from below; *c*, rudimentary wing pad; *d*, mouth parts. All enlarged. (Howard and Marlatt, Bull. Div. Ent., U. S. Dep. Ag.)

One of the worst pests of the Mississippi Valley, and a common insect over the entire eastern United States, is the chinch bug. During winter chinch bugs are in the adult stage, and may be found secreted under grass, dead leaves, rubbish of various kinds, both in the fields and in thickets or timber, especially along the

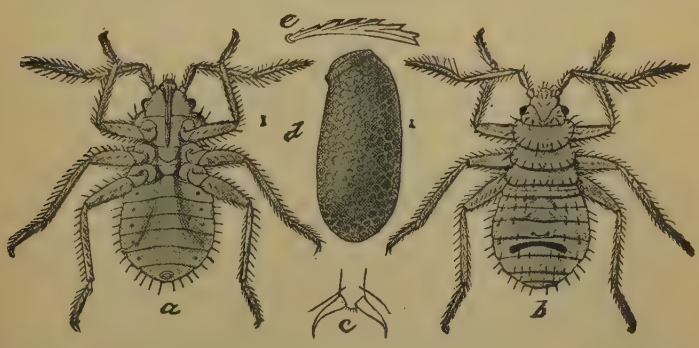


FIG. 165. — **Cimex lectularius.** Egg and newly hatched larva of bedbug. *a*, larva from below; *b*, larva from above; *c*, claw; *d*, egg; *e*, hair or spine of larva — greatly enlarged; natural size of larva and egg indicated by hair lines. (Howard and Marlatt, Bull. Div. Ent., U. S. Dep. Ag.)

borders of thickets or woods, under leaves, loose bark, etc. In the spring, these adults issue, and after finding suitable plants for the food of the young, deposit their eggs on stems at or just beneath the surface of the ground. The eggs are about one thirty-second of an inch in length, rather slender, slightly curved and of a yellow color. One end (the head end) is truncated or apparently cut square across, and on this end are four small granules or tubercles, too small to be seen with the naked eye. The egg becomes darker as it nears the time for hatching, and at the head end the eyes may be seen plainly through the egg walls. Each female is said to be capable of laying about five hundred eggs, occupying about twenty days in their deposition, so that if wet weather destroys those deposited at one time, others are likely to escape. The process begins in April (possibly earlier in favorable seasons) and extends into May. If wheat is available, this will be the principal crop attacked at this time, but eggs may also be laid in oats, rye, barley, corn, and various grasses. The bugs depositing eggs live for some time afterward, if plenty may even do some damage to the crop, but usually they are too few in number to cause trouble, and they gradually die off till by the time their offspring mature they are mostly dead.

The eggs hatch into minute yellow or light red bugs, which

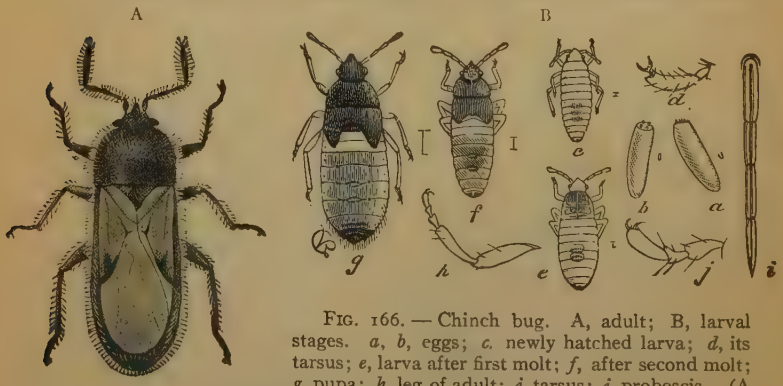


FIG. 166. — Chinch bug. A, adult; B, larval stages. *a*, *b*, eggs; *c*, newly hatched larva; *d*, its tarsus; *e*, larva after first molt; *f*, after second molt; *g*, pupa; *h*, leg of adult; *j*, tarsus; *i*, proboscis. (A after Webster, B after Riley, Bur. Ent., U. S. Dep. Ag.)

have the same general form as the adults. They begin feeding on the roots of the plant, where the eggs were laid. (Eggs, it is said, may be laid above ground, but they are almost always found on the stems or roots of the plant, half an inch or more beneath the surface.) After growing for a time the larva sheds its skin, assuming a darker color, but retains a light band across the middle of the back. After growing for another period it molts again, assuming after this molt a brownish color with a whitish line across the back. After still another molt, it becomes nearly black save the white band on the back, and in this stage the wing pads become well developed, indicating the pupa stage, and then another molt occurs (really the transformation from pupa to adult), and the insect assumes the winged condition. It is now three sixteenths of an inch long, of a deep black color, and with white wings, which have a black spot on the border near the middle. Bugs which have hatched in April or May become mature in the latter part of June or July, and after pairing another lot of eggs is deposited to produce a second brood of bugs. The bugs which have been feeding on wheat, however, find upon its ripening that they must migrate or starve; so that there is a general movement of bugs, both mature and partially developed, from wheat fields into corn, etc., accomplished, as a rule, on foot by the winged bugs, as well as the immature ones. Sometimes in July there is a general flight of bugs, and at such time the air will be full of bugs, and the fields which have not been previously infested will swarm with them. This is bad enough, but as each female of this swarm deposits hundreds of eggs, it is not long till the field is so packed with bugs that the plants rapidly succumb. On corn they will cluster on the stalks from the roots to near the tops of the leaves; while on grasses, such as Hungarian, foxtail, etc., every part of the plant may be crowded with them. The second brood attains its growth during the late summer and fall, and by the time cold weather approaches nearly all have reached the mature form and are ready to secrete themselves for the winter.

The remedies for this species must depend in large part upon conditions, but, in brief, may be summed up as follows: Burn all rubbish, dead grass, etc., in fence corners, and along thickets, to destroy the bugs in late fall or early spring. In seasons when bugs are likely to be numerous arrange to plant so as to avoid as much as possible the favorite crops for their food, reducing wheat, rye, barley, and Hungarian grasses as much as possible, and planting potatoes, turnips, rape, buckwheat, or crops not eaten by the bugs. Where possible separate wheat fields from corn

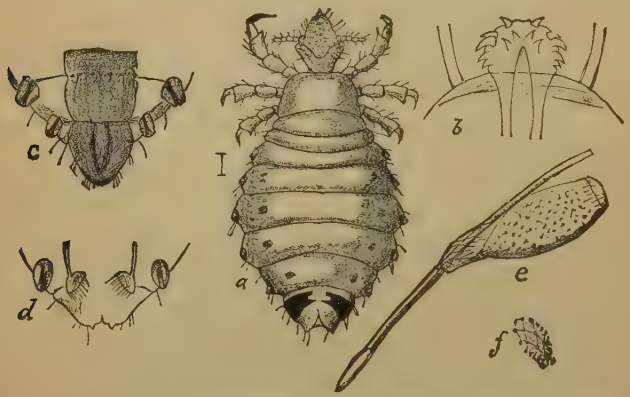


FIG. 167. — Ox louse, **Hæmatopinus eurysternus**. *a*, female; *b*, rostrum; *c*, ventral surface of the last segments of male; *e*, egg; *f*, surface of same greatly enlarged. (Author's illustration, Bull. Div. Ent., U. S. Dep. Ag.)

by planting of potatoes or unliked crops, even a strip of a rod or two being useful in deterring the migration to corn. During migrations obstruct movement by dusty furrows, and if stubble is dry enough, burn, to destroy migrating bugs. Where bugs collect on corn rows at margin of field, use kerosene emulsion.

The Parasita, while extreme in the degeneration of many structures and specialization of those concerned in their parasitic life, show relationship to Hemiptera in the mouth parts. The group includes many species, all of which occur as parasites upon mammals. Some of them are of great importance as pests of live

stock. The horse lice, cattle lice, hog lice, and others are sources of much loss. Three species infest man.

Order Neuroptera. — As at present restricted this order includes a small number of insects with complete metamorphosis, biting mouth parts and net-veined wings. Among the more striking species is the Hellgramite fly, the aquatic larva of which is found under stones in swiftly running water. The Lace-wing flies abound in the vicinity of aphid colonies, and their larvæ, known as " aphis lions," are very active and useful in the destruction of the aphids. The ant lions live in sand or loose earth as larvæ, some of the species making pitfalls in which they capture ants and other small insects.

Order Mecoptera. — Scorpion flies. A small group of but little economic importance.

Order Trichoptera. — Caddice flies. These have biting mouth parts in both larval and adult stages and the larvæ are aquatic, but they present many characters which show them to be related to the Lepidoptera. Apparently from some primitive form of the group, probably terrestrial in habit, the primitive forms of Lepidoptera had their origin.

Order Lepidoptera, moths, butterflies, etc., forms one of the largest orders of insects, including a great number of subdivisions and including some of the most brilliant forms and some of the extremes in size. They are separated from all other insects by the mouth structure, it being adapted for sucking up nectar of flowers, and this structure being developed largely from the maxillæ, the parts being elongated and extended for some length when in use, and when not in use rolled up like a watch spring. Some forms have remnants of rudimentary mandibles, but in most cases these cannot be found. When they occur the mouth parts seem to be in their general structure related to those of the Trichoptera. The larvæ are mandibulate. Another distinctive character is the complete covering of body and wings with minute scales.

The Lepidoptera show quite an extreme condition in metamorphosis. The larvæ are known as caterpillars. They usually have

a series of prolegs or false legs developed on the abdominal segments. The more common number is ten, four pairs located on the central abdominal segments and one terminal pair. These are not homologous with the segmentally jointed appendages of insects generally. They stand out prominently and are fitted commonly with rows of small hooks or teeth at the margin. The larvæ are elongate and generally cylindrical and are followed by a pupa stage strikingly different from the larval stage and frequently inclosed in a cocoon. This is a quiescent stage. The adult on issuing splits the pupal case along the dorsal portion and crowds its way out.

Codling moth. — One of the worst pests we have and one which causes the greatest loss in orchards is the codling moth (*Carpocapsa pomonella*). The loss is estimated at millions of dollars in such states as New York, Ohio, Illinois, and other states where apple growing is an important industry. The life history of the species has been well known for many years and furnishes the basis for successful treatment, so that there is no longer excuse for permitting wormy apples on the markets. The adult moth issuing from a pupa that has passed the winter deposits its eggs on or near the fruit, and the larva on hatching eats its way through the surface almost invariably within the calyx, after which it feeds until full grown within the pulp of the fruit, especially around the core. When fully grown it issues from the fruit, crawls down the tree unless the apple has fallen, secretes itself under loose bark or some protecting corner, spins a slight cocoon, changes to pupa, and in about nineteen days issues as a moth. This occurs about the middle of July, and after mating eggs are deposited for a second brood of larvæ which feed within the apples during late summer and are found in the fruit during fall and early winter. These late larvæ issue from the fruit and pupate in the orchard or in fruit cellars where fruit is stored, to mature as moths the following spring. The time of entering the fruit, especially for the first brood, is the critical period for treatment, and arsenical applications in the form of sprays applied so as to get the poison lodged

in the calyx of the apple is the most successful method of treatment. The application should be made immediately after the fall of the bloom, before the calyx has closed in, and may be repeated, especially if there have been heavy rains, a week or ten days after first application.

The gipsy moth is of great interest as an instance of an introduced species which has become very destructive and which has spread from the center of introduction so that it is likely in time to invade all of the eastern United States at least. It is a common European species, was introduced for the purpose of experiment,

FIG. 168. — Gipsy moth, **Porthetria dispar**, female moth. (After Howard, Bull. Bur. Ent., U. S. Dep. Ag.)

and escaped accidentally, and after a few years became conspicuous in its attacks on the foliage of various shrubs and trees. About the year 1889 it became so destructive that the state of Massachusetts undertook to exterminate it, and expended during several years something over a million dollars in the attempt. The effort, however, was suspended, and while the insect had been much reduced in numbers and its extermination seemed possible, a few years of freedom enabled it to reëstablish itself and spread into more distant localities and adjacent states. The effort at present in which different states and the National Government are concerned is to suppress it as far as possible and to control it

where extermination is not possible. Another recent introduction of great importance is the brown-tail moth.

The silkworm may be counted essentially a domesticated insect, since it is so universally cared for by man and since in all probability it would be hardly able to survive under present conditions without human care. Its product is probably the most

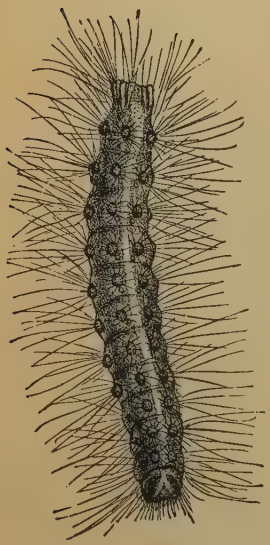


FIG. 169. — Gipsy moth larva. (After Howard, Bull. Bur. Ent., U. S. Dep. Ag.)

FIG. 170. — Gipsy moth pupa. (After Howard, Bull. Bur. Ent., U. S. Dep. Ag.)

important commercially of that of any insect. The silk industry is of special importance in China, Japan, France, and Italy, and while silk growing is as yet but little developed in the United States, the manufacture of silk goods and the commerce connected with them is a very important item. The silkworm was a native of southern Asia, and its domestication dates back into antiquity,

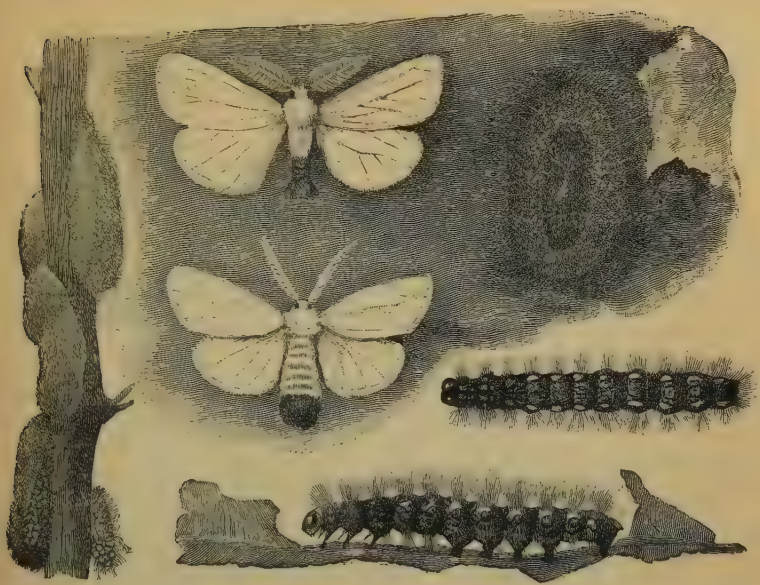


FIG. 171. — Brown-tail moth, **Euproctis chrysorrhœa**. Moths, larvæ, and cocoons. (After Howard, Bur. Ent., U. S. Dep. Ag.)

FIG. 172. — Silkworm, **Bombyx mori**. A, female; B, male. (From Shipley and McBride.)

as does also the manufacture and use of silk as a fabric. The silkworm moth is a heavy-bodied insect with small wings, those of the female being too weak for flight, possibly the result of domes-

tication. Each female lays a large number of eggs, the larvæ feed on mulberry leaves or will feed readily on the leaves of osage orange, and must be provided with fresh food at frequent intervals, the common practice being to pick the leaves and feed them to the larvæ to avoid the exposure upon plants. Their growth is

FIG. 173. — Walnut tree defoliated by caterpillars of the Handmaid moth, **Datana angusi**. (From photograph by the author.)

rapid. They molt four times, and as they reach full growth the silk glands become enormously developed, so that when the larva spins its cocoon for pupation, it produces an enormous length of silk thread which is wound continuously, beginning, of

course, on the outside and finishing within, and within this cocoon the larva changes to the pupa stage. If left to develop, the adult issues from the pupa the following spring, but in practice the

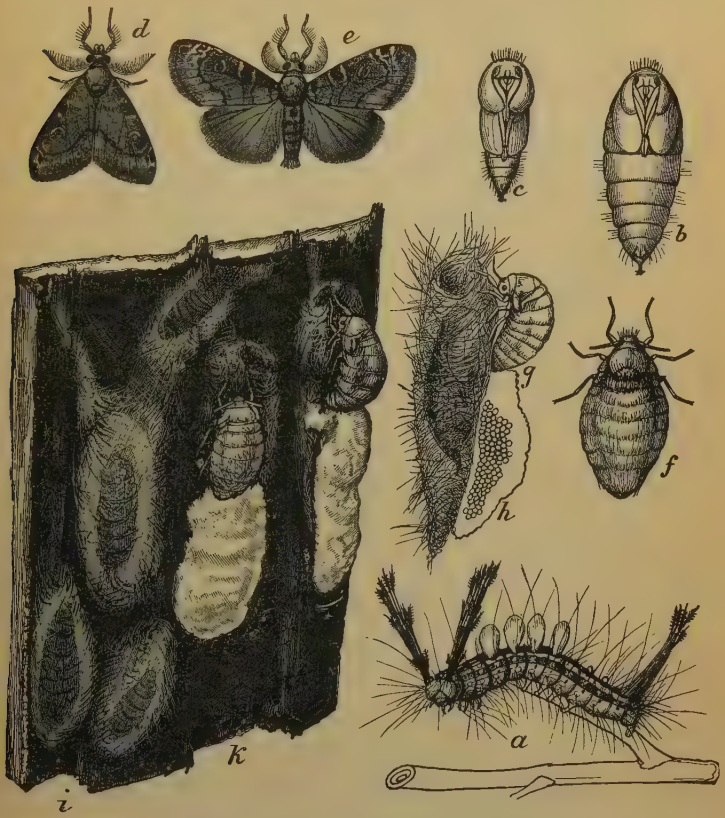


FIG. 174. — Tussock moth, **Orgyia leucostigma**. *a*, larva; *b*, *c*, pupæ; *d*, *e*, adult male; *f*, female; *h* and *k*, egg masses. (After Howard, Div. Ent., U. S. Dep. Ag.)

cocoons which it is intended to use for silk are killed by immersion in hot water and the silk is unwound.

Other members of this order which may be mentioned as im-

portant are the destructive fall webworm, walnut caterpillar (see Fig. 173), cutworm, army worm, tussock moth, canker worm, peach borer, cabbage worm; and there are many others nearly if not equally important; and there are many species like the cecropia, promethea, luna moths, and the swallowtail and

Fig. 175. — Peach borer, **Sanninoidea exitiosa**. *a*, female; *b*, male; *c*, larva; *d*, pupa of female; *e*, pupa of male; *f*, cocoon. (After Marlatt, Bur. Ent., U. S. Dep. Ag.)

other butterflies which are very interesting on account of their beauty and the striking metamorphosis which they exhibit. Butterflies are day flying and are distinguished by having a distinct knob at the end of the antennæ, while the moths with few exceptions are nocturnal and their antennæ taper to a fine point and are frequently provided with feathery barbs.

Fig. 176. — Butterfly, **Pieris rapæ**, with (*a*) caterpillar and (*b*) chrysalis stages. (After Riley.)

Order Coleoptera is the order of beetles—one of the immense groups of insects, both in species and individuals. It is one of the most distinctly marked groups. In some ways it is more specialized, in others more generalized. The wing structure is specialized; horny front wings, which are useless so far as flight is concerned, serve as covers for the wings of flight and for the abdomen. The hind wings are the organs of flight. The reduction of the front wings is to be noticed in a number of cases. In some species they cover only a small portion of the body. The Coleoptera and Diptera, so far as wings are concerned, are about equally specialized. In the mouth parts the Coleoptera are very much less specialized than the Diptera, as they retain the primitive structure. The mandibles are reduced, in some groups, but are functional even in the adult stage. They are not modified into suctorial organs. Metamorphosis is quite distinct. There are the four stages common to insects, and in some groups the larvæ are quite specialized, and there are different larval forms. The beetles have been studied perhaps more than any other group except the Lepidoptera. They are more easily preserved than a great many and more conspicuous. The beetles probably number at least one hundred thousand species, and in this country ten or twelve thousand species are recognized. A considerable number of these are of economic importance. The group is separable into two quite distinct divisions. The Rhynchophora are the more specialized. The head is drawn out in a snout and the mandibles are much reduced in size. The larval forms are more specialized. There are numerous examples of this.

The Colorado potato beetle may serve as a fair example of the order, although it is now much less abundant and destructive than a quarter century ago. It may be found, however, in almost all parts of the country, attacking potatoes, and its various stages are easily observed. The adult is about one half inch long, yellowish, with ten black stripes on the two wing covers. The adults hibernate underground and often at considerable depth, issuing in spring and depositing eggs upon the leaves of newly started

potatoes, usually attaching them in clusters on the under surface of the leaf. They are golden yellow, and hatch in a few days into small brick-red grubs with some black markings, the color growing lighter with succeeding stages and increase in size. They molt about five times, growing rapidly, and when abundant devour potato vines in a very destructive manner. They complete the larval growth in about three weeks and then burrow underground

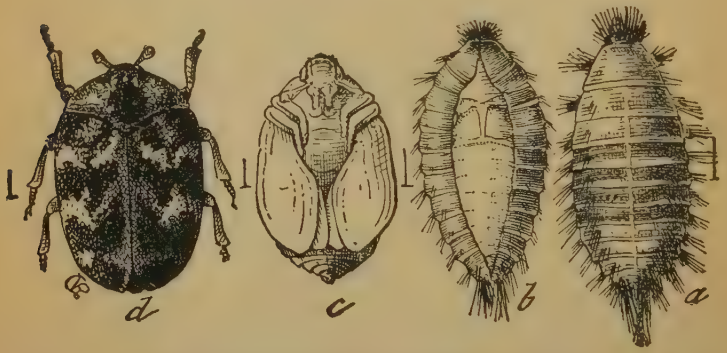


FIG. 177. — *d*, Carpet beetle (**Anthrenus scrophulariæ**), with larva, *a*, *b*, and pupa, *c*. (After Riley, from Bull. Div. Ent., U. S. Dep. Ag.)

a little distance and change to the pupa stage, which differs from the larva very distinctly in shape and is of a much lighter color. The pupa stage lasts about ten or twelve days, and the adult emerges, and issues from the ground in early summer. Eggs are laid by the females of this brood, and another generation of larvæ, often enormously more plentiful than the first, appears in mid-summer, and unless attended to may occasion complete destruction of the potato vines. These complete their growth, pupate, and become adults in late summer or early autumn, and later burrow underground for hibernation.

This insect was first noticed nearly a century ago in the Rocky Mountain region, being described by Thomas Say about 1820. Originally it fed upon a native Solanum, the spiny nightshade, but on introduction of the potato into its habitat the insect adopted

this as a food plant, and doubtless because of the greater supply of food increased beyond its natural rate and soon commenced a migration eastward. This migration resulted in a general distribution of the species over the entire eastern United States, the Atlantic coast being reached in the seventies; and later the insect became a world traveler and visited Europe. For many years it was an extremely destructive pest and the necessity for its control was perhaps the most important factor in the develop-

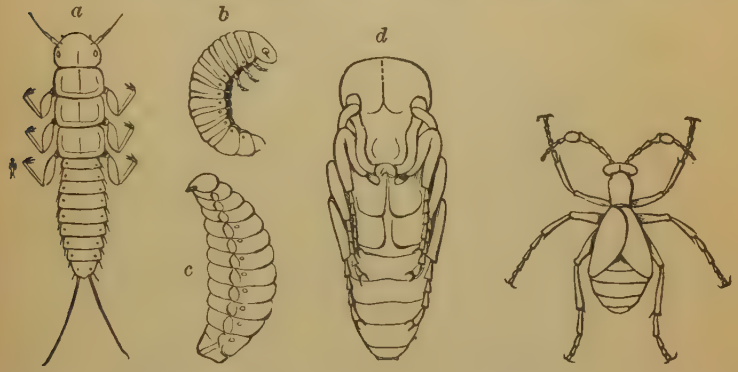


FIG. 178. — Oil beetle, **Melœ**, *a*, first larva; *b*, second larva; *c*, third larva; *d*, pupa. (From Packard's *Text-book*.)

ment of methods of destruction of insects by means of arsenical poisons, and especially of the spraying methods with Paris green and other arsenical poisons. These methods were developed so that in time the insect was very readily controlled and ceased to be the serious menace to the potato-growing industry which it had previously been. Another factor, however, in the diminution of its number and the lessened injury from it was doubtless the development of numerous natural enemies, such as predaceous insects that preyed upon the eggs and larvæ.

Another form, the very destructive carpet beetle, or "buffalo moth," is shown in its different stages of growth in Fig. 177.

Order Diptera. — The insects of this group are readily distinguished by their having only one pair of wings, the second pair common to other insects being represented by a pair of rudiments or modified structures called halteres or balancers. In many of the parasitic forms, however, the wings are entirely wanting, as in the sheep tick, spider fly, etc. They have suctorial mouth parts, and, in the forms attacking the various animals, these parts become readily adapted to penetrate the skin in order to reach the small blood vessels.

FIG. 179. — A midge, **Chironomus sp.** (Original.)

The larvæ are fleshy grubs or maggots, or slender worms, adapted in the different families to widely different conditions of existence, but in nearly all cases requiring some degree of moisture. In this respect they range all the way from the entirely aquatic mosquito larvæ to the forms which mature in comparatively dry situations in earth or even upon plants.

The pupæ are in some cases formed by the simple contraction and hardening of the larval skin, and in disclosing the imago may either split on the dorsal surface or in a circular manner so that a cap is separated from the head end, leaving a round aperture through which the adult emerges.

While comparatively few are parasites in the strictest sense, the group includes many of the most troublesome of the insect

enemies of live stock, as will be recognized in the discussion of particular species.

Mosquitoes (*Culicidæ*) are slender-bodied, delicate insects with gauzy wings, the veins of which bear minute scales. The mouth parts are provided with lancet-like, piercing mandibles, which, in the females, are capable of inflicting a severe bite.

The larvæ in those species whose life history has been traced are aquatic, and this may doubtless be considered as the usual habit for the family.

Eggs are deposited on the surface of water and the larvæ hatching from these escape into the water. They move about by a jerky motion, often ascending to the surface to obtain a fresh supply of air, which is taken through a slender tube at the caudal end. The pupae are also active and move about in the water during their brief existence in this form, rising to the surface for air, which is taken through a spiracle near the head. When the insect is ready to emerge the pupa rests at the surface of the water with the dorsal portion slightly out of the water, the case splits and the mosquito draws out first the front legs, which are placed on the water to serve as support while the rest of the body is withdrawn. The wings expand very quickly and the insect flies away.

The relation of mosquitoes to malaria and other diseases is of great importance and has been referred to under the Protozoa.

The Hessian fly is a serious pest of wheat, occurring in practically all wheat-growing regions of the world, although usually most destructive in the winter wheat districts. It occasions enormous losses during some years in the central United States, the loss for the state of Ohio for the year 1902 being estimated at from sixteen to twenty millions of dollars. The insect was introduced into the United States, probably from Europe, about the time of the Revolution, and the name "Hessian fly" was applied to it because of the supposition that it was introduced with the Hessian soldiers sent over at that time, or, possibly, as a term of obloquy.

The name is now used quite generally over the world. Its food plants are wheat, rye, and barley, and it seems to be very closely restricted to these plants, with wheat as the most preferred.

The life cycle is definitely adapted to the growth of wheat, a brood of adults appearing in autumn, depositing eggs on newly started wheat, the larvæ, which work down between the leaf and stem, feeding upon the juices of the plant and causing more or less distortion of the stem. They complete their growth before winter and change to the "flaxseed" stage, the contracted larval skin forming a tough covering within which the larvæ change to pupæ. In spring, adults issue and deposit eggs which produce a spring brood of larvæ. These most commonly occur in about the first joint above ground, and by their attack on the stem cause it to break open or bend over before the wheat has ripened. The falling of the wheat prevents its ripening perfectly, or, if ripened, it is lost in the harvest. The "flaxseeds" formed in the stems are usually left in the stubble, although some occurring in higher joints may be cut with the straw and in this manner possibly carried to distant points.

Transportation by means of straw or chaff is probably the only means by which the insect is carried from one country to another. The distribution by means of its own flight or by local scattering of straw is considered as only about twenty miles each year. While two broods are the normal number, suitable conditions of moisture and food plants may produce additional broods during the summer; but in usual conditions, practice may be based on the occurrence of two broods. Continued dry weather serves

FIG. 180. — A wheat plant showing an uninjured stalk at left and one infested with Hessian fly at right, the latter dwarfed, leaves withered, and stem swollen at three points near the ground, where the "flaxseeds" are located, between the leaf sheath and stem. *a*, egg of Hessian fly, *9* greatly enlarged, as are all figures except *e* and *h*; *b*, the larva, enlarged, the line by the side showing natural length; *c*, the puparium, "flaxseed," or pupa case; *d*, the pupa, or chrysalis; *e*, adult female, natural size, ovipositing; *f*, adult female, much enlarged; *g*, male, much enlarged; *h*, "flaxseed" in position between leaf sheath and stalk; *i*, parasite, **Merisus destructor**, male — enlarged. (From Packard, Third Report U. S. Entomological Commission; *b*, drawn by Dr. Riley; *d* and *f*, by Mr. Burgess; *a*, *g*, *c*, *i*, by Packard.)

FIG. 180.

to retard the emergence of the fall broods, so that adults come out under conditions which coincide with the growth of wheat plants in autumn.

Numerous parasites affect the species and are a very important factor in keeping it in check. In fact, these are the main things which prevent extensive losses every year. The measures that may be adopted for its control consist entirely in methods of farm practice or culture, as no direct application is possible. Burning or plowing under of stubble in midsummer, the earlier or later planting of the crop, the use of trap crops, are some of the methods. Numerous reports discuss its habits and remedies in detail.

The buffalo gnats, which are a scourge to cattle in many places, the horse flies, which are well-known pests, and the bot flies infesting horses, cattle, sheep, etc., are other forms of great economic importance.

The common house fly is a cosmopolitan species, a nuisance in houses the world over, or at least in all temperate and tropical climates. Its larval stages are passed in decaying organic matter, most commonly in horse manure, and the disposal of all such material would greatly lessen if not completely eliminate the nuisance. Aside from the extreme annoyance occasioned by its presence in houses there is extreme danger of its carrying disease germs in its visits from refuse to food materials. If it chances to feed upon fæcal matter containing germs of typhoid fever and later rests upon food eaten without subsequent cooking, infection with this disease is extremely probable. It was very definitely determined that the epidemics of typhoid fever in the camps during the Spanish-American War were due to this source of infection. The use of screens for houses, and especially for rooms in which food is prepared, is therefore an important matter; but the prompt disposal of garbage and stable waste, if made general in a community, would practically abate this nuisance and source of danger.

The blow flies, blue bottle flies, screw-worm flies, horn fly, and stable fly are other forms of much importance.

A

B

FIG. 181. — **Gastrophilus equi** in stomach of horse. A, bots on the walls of a horse's stomach. (From a photograph by the author.) B, Portion of stomach wall showing points of attachment of bots. (From a photograph by the author, Bull. Div. Ent., U. S. Dep. Ag.)

The family *Hippoboscidæ* includes sheep ticks and forest flies. They have the wing structure of the Diptera, suctorial mouth parts, but a very remarkable method of reproduction. Instead of being extruded the eggs are retained in the oviducts and developed through the larval stage, being nourished by nutritive

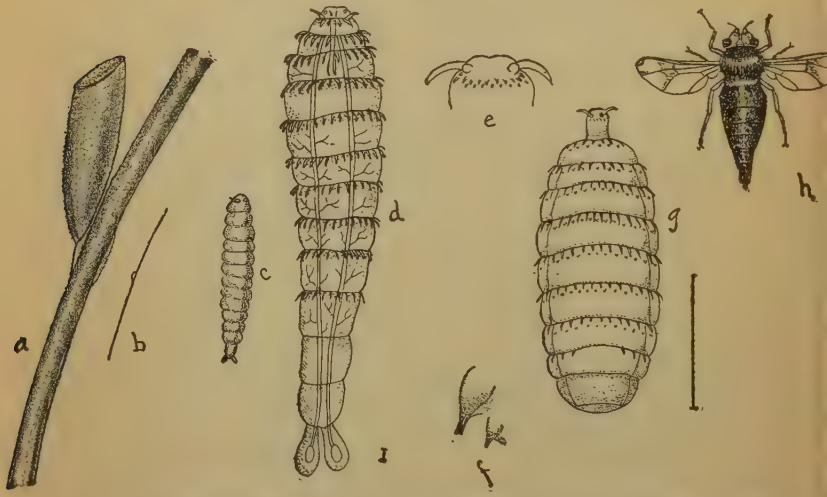


FIG. 182. — **Gastrophilus equi.** *a*, egg, enlarged; *b*, egg, natural size; *c*, young larva; *d*, young larva, much enlarged, showing spiny armature; *e*, oral hooks; *f*, body spines; *g*, full-grown larva, twice natural size; *h*, adult female. (Author's illustration, Bull. Div. Ent., U. S. Dep. Ag.)

fluids from the adult. They are not extruded until they are ready to pass into the pupa stage. They take no nutriment as pupæ after leaving the oviducts, so there is no food taken independently until, as adults, they puncture a host animal and suck its blood. There is thus an extreme adaptation for the parasitic habit, and a different sort of adaptation than is found in any other group of Diptera, except the succeeding family. They are indeed very different in this respect from any other group of animals. The species that is most widely distributed and best known is the sheep tick, and this is entirely wingless and depends upon

moving from one sheep to another for its dispersal and survival. Its control is dependent quite largely upon methods of dipping. The most effective dipping can be accomplished shortly after shearing, while the fleece is thin.

The *Nycteribidæ*, or bat ticks, are another family of extremely specialized parasitic, wingless forms occurring as parasites on bats.

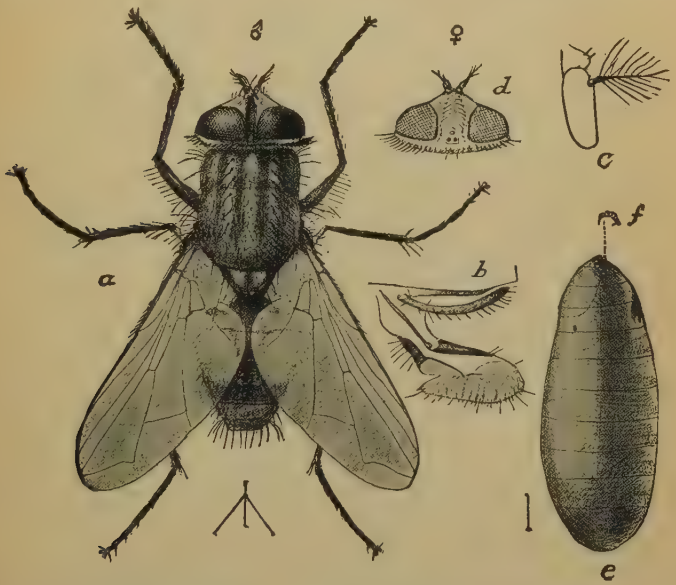


FIG. 183. — **Musca domestica**. *a*, adult male; *b*, proboscis and palpus of same; *c*, terminal joints of antennæ; *d*, head of female; *e*, puparium; *f*, anterior spiracle. All enlarged. (After Howard and Marlatt, Bull. Div. Ent., U. S. Dep. Ag.)

Order Siphonaptera. — These are wingless or have the wings so aborted that they are practically wingless. Vestiges of wings occur, but are useless as organs of locomotion. They have suctorial mouth parts. The adults puncture various kinds of animals, sucking blood for their food supply. The larvæ are slender and live in refuse and rubbish, litter of dog kennels, etc., and when

mature, change to a very distinct pupa stage and then to the adult fleas. The pupa stage is like the adult in shape, but the legs, etc., are incased in the rigid pupa case. The hind legs are specially developed and their mode of progression is by leaping. They occur on different kinds of animals, the dog or cat flea as well as the human flea attacking man. Others occur on squirrels,

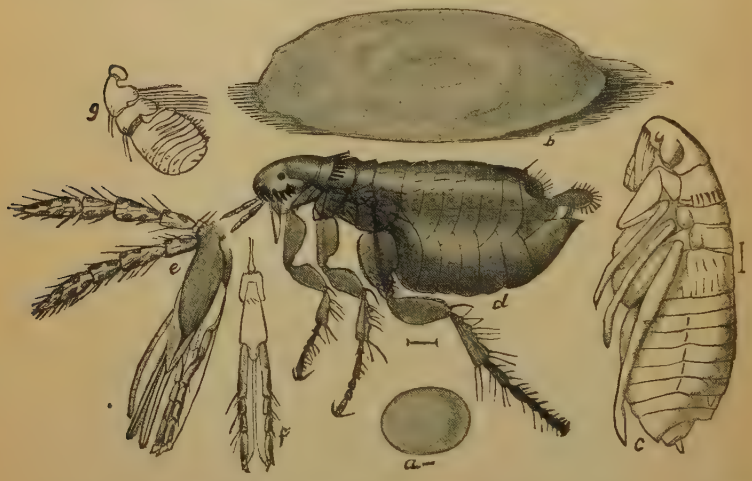


FIG. 184. — **Pulex serraticeps**, dog flea. *a*, egg; *b*, larva in cocoon; *c*, pupa; *d*, adult; *e*, mouth parts of adult from side; *f*, labium from below. (Howard and Marlatt, Bu. Ent., U. S. Dep. Ag.)

rats, mice, and various other mammals, mainly on the smaller species of mammals, but one species occurs on various birds and one species attacks poultry. It buries itself in the skin something like a jigger, though not so extreme in the extent to which it will burrow. The jigger flea, or "chigoe," occurs in tropical regions and is a serious annoyance to man, its common mode of attack being to burrow under the toe nails, where it may lay eggs, die, and cause troublesome sores.

Order Hymenoptera have four wings, and these are provided with rather few veins and are pretty highly specialized in the venation,

and in a very few groups the veins are practically reduced to nothing. They are both mandibulate and haustellate. The

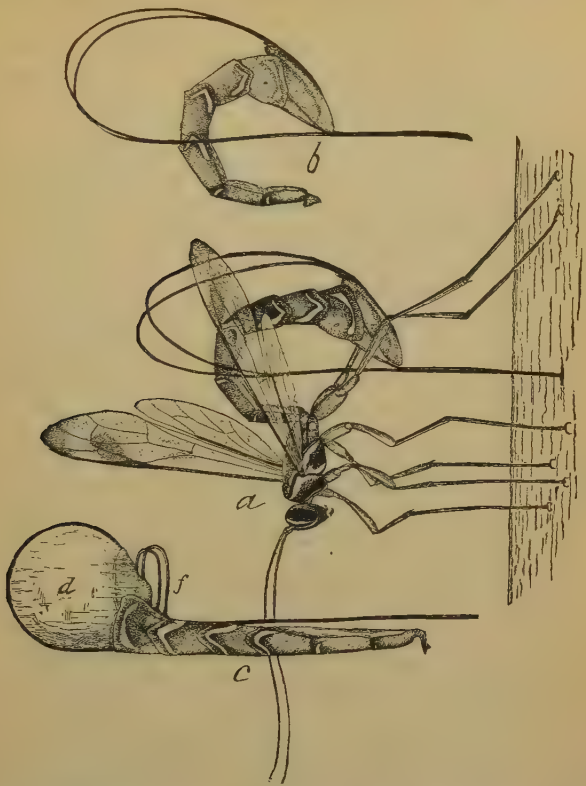


FIG. 185. — **Thalessa lunator**. *a*, female in act of ovipositing; *b*, abdomen showing outer sheaths in slightly different position; *c*, abdomen stretched to its utmost, as when first inserting or finally withdrawing the ovipositor, and showing the coil of outer sheaths *f*, the distended membrane *d*, and the ovipositor coiled around inside it at periphery. (From *Insect Life*, Div. Ent., U. S. Dep. Ag.)

mandibles are present for the most part in the adult, but are almost lost in some larval forms that are fed by the adults in communal states. The larvæ are usually footless, fleshy, grub-like

animals which depend on their food being supplied to them in one way or another, and except among the saw flies and horn tails are incapable of moving about and securing their own food supply. This represents a high degree of specialization and reaches its culmination in the community habit of ants and bees. In no other group except the white ants is there such development of the community habit.

The order is a very large one, including an immense number of species and showing a great variety of habits, and, economically, varying from quite destructive forms to some of our most useful

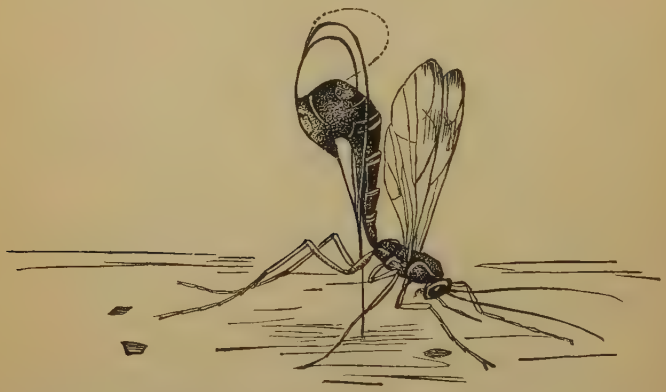


FIG. 186. — **Rhyssa persuasoria** ovipositing. (After the *American Agriculturist.*)

species. Certain families are external leaf feeders in the larval stages, others wood borers, others again produce remarkable growths of plants which are called galls, many are parasitic upon other insects and in their parasitism show most remarkable instances of dimorphism and adaptation to the life cycle of the host form. The egg parasites are extremely minute forms, attaining

FIG. 187. — **Thalessa lunator.** *a*, larva; *b*, head of larva, from side; *c*, pupa; *d*, ovipositor of pupa; *e*, adult female; *f*, abdomen of female, side view; *g*, adult male; *h*, tip of abdomen, male. (*Insect Life*, Div. Ent., U. S. Dep. Ag.)

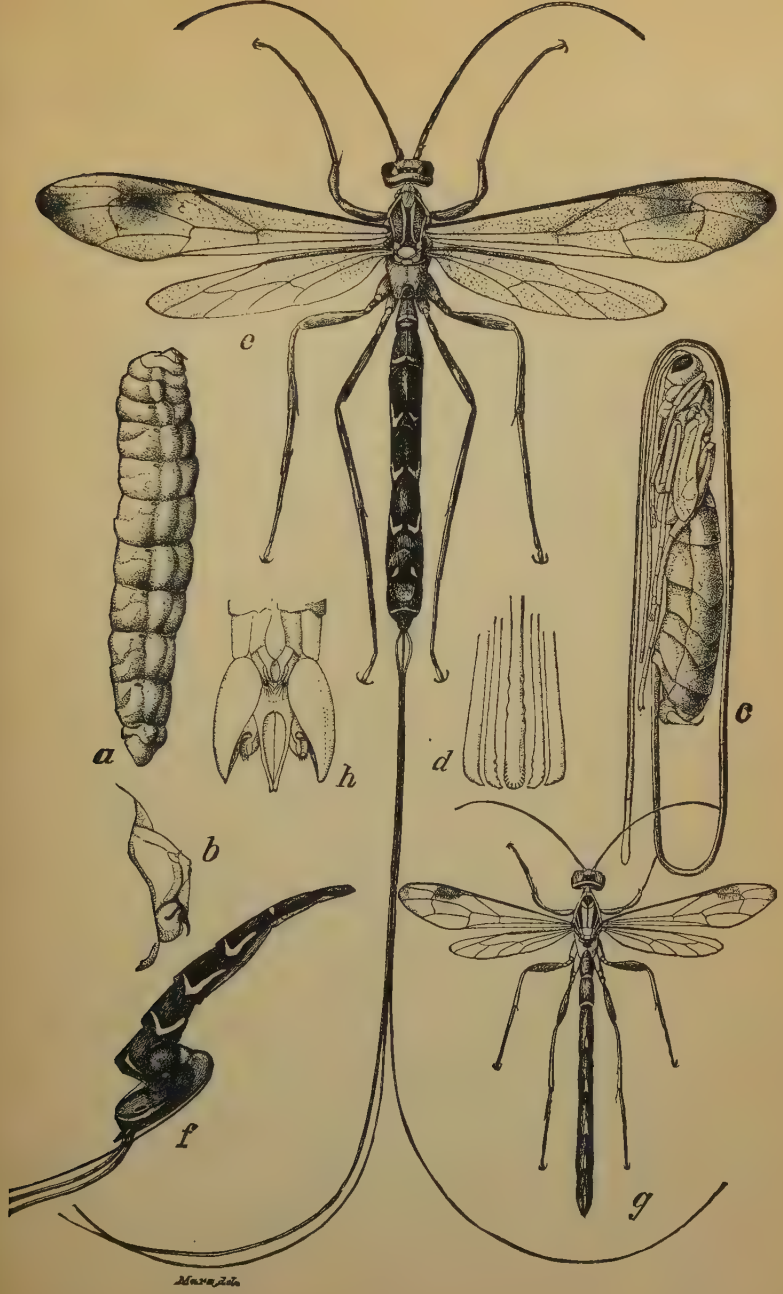


FIG. 187

their entire growth within the eggs of insects. Sometimes the eggs are of very minute size, and the full-grown adult parasite may be almost microscopic in size. The smallest known species, in fact the smallest known insect, is less than one hundredth of an inch in length. In parasitizing the eggs of insects, their relation is,

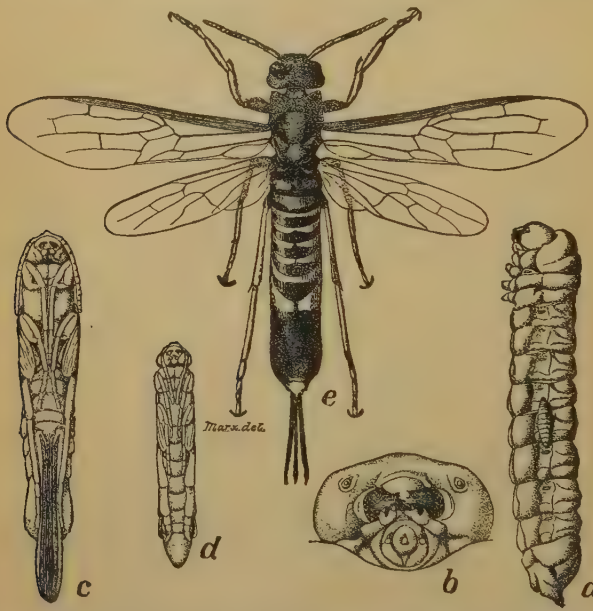


FIG. 188. — **Tremex Columba**. *a*, larva, showing **Thalessa** larva attached to its side; *b*, head of larva, front view, enlarged; *c*, female pupa, ventral view; *d*, male pupa, ventral view; *e*, adult female. All slightly enlarged. (From *Insect Life*, U. S. Dep. Ag.)

of course, dependent upon the character of the insect it attacks, those which attack useful insects being injurious, and those attacking destructive forms being beneficial. Then there is frequently a condition called secondary parasitism, in which one parasite is parasitic upon the parasite of a primary host, and this secondary parasite would of course have exactly the reverse relation of the primary parasite. Still further, there are tertiary parasites known

living within the secondary parasite, and even parasites upon the tertiary parasite, so that the relations of the parasitic forms and their actual places as beneficial or injurious forms become extremely complicated.

Formicina. — Ants are one of the most interesting groups of insects. They are sometimes given the rank of a super-family, but the principal families are Poneridæ, Myrmicidæ, and Camponotidæ. The name Formica is associated with the secretion of formic acid. The name of the group probably gave the name to the chemical. The secretion is one of the characteristics of the Hymenoptera. Ants present striking habits of community life, — the formation of different classes among the individuals of a colony. This separation into classes is paralleled in other groups, as in the bee family. The result of community life is to establish certain relations in the community in the way of division of labor. The primary forms are males and females, and then a class which are not sexual, but are derived from a modification or suppression of the reproductive factor in one of the sexes. Occurring with this is the reduction or complete absence of wings in the so-called workers or soldiers of a colony. The workers have no traces of wings, and their origin reaches pretty far back into the ancestry

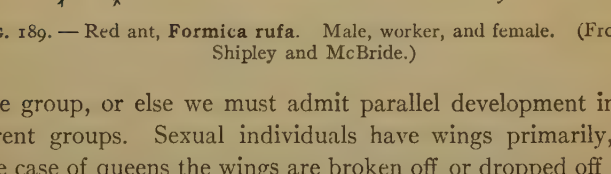


FIG. 189. — Red ant, **Formica rufa**. Male, worker, and female. (From Shipley and McBride.)

of the group, or else we must admit parallel development in the different groups. Sexual individuals have wings primarily, but in the case of queens the wings are broken off or dropped off after the flight associated with pairing. Then the females are unable to travel and remain fixed in a certain colony and furnish offspring for the colony. A group of ants is called a formicary. It may vary in number of individuals from a few hundreds to

thousands. A single queen ant may survive for a great number of years and the same colony may go on for many years. The usual course of the life cycle is for winged females to issue from some colony and make the flight that is connected with mating and then to burrow into the ground or select a suitable nest in which to place the eggs and begin the formation of a new colony. The fertilized queen is capable of producing workers, and in some cases the queen alone will start a colony. In some forms, perhaps, the help of neuter ants is needed. After the starting of the colony by the deposition of eggs a colony becomes more populous. Differentiation has not gone quite so far in ant colonies as in some others, but polymorphism has gone much farther. The workers of the colony take care of the eggs and the young and shift the young about, and if the nest is disturbed they carry the pupæ to a place of safety. The pupæ are of course helpless. The workers and soldiers die off pretty rapidly. They survive through the working period, and when they die are replaced by other workers. The colony retains its individuality year after year. The life of the colony is probably at least as long as the life of the queen, and probably continues longer than that. Otherwise the colony would have to terminate soon after the death of the queen. The multiplication of colonies is provided for by the issuing of new queens from the colonies, and the ability of the ant to survive depends as much on its ability to form new colonies as new individuals. The cycle is probably pretty exact for annual periods in each season. The females are probably produced annually. The food of the ants is primarily plant food. They collect nectar and various substances of vegetable origin, and the workers are responsible for the collecting and storing and using of the food supply. Indirectly they get such supplies from the aphids. They store up grain in some instances and they probably use this grain to some extent at least as a food supply. Other species — the honey ants — collect honey and store it in the stomachs of certain individuals of the colony. The bodies of these individuals become very much distended, the abdomen be-

comes large and spherical, and these keep the food for a part of the year. Such an ant occurs in the plateau regions of Colorado, particularly in the Garden of the Gods. An interesting account of these may be found in a book by Dr. McCook. Lubbock's book on Ants, Bees, and Wasps also contains much of interest in

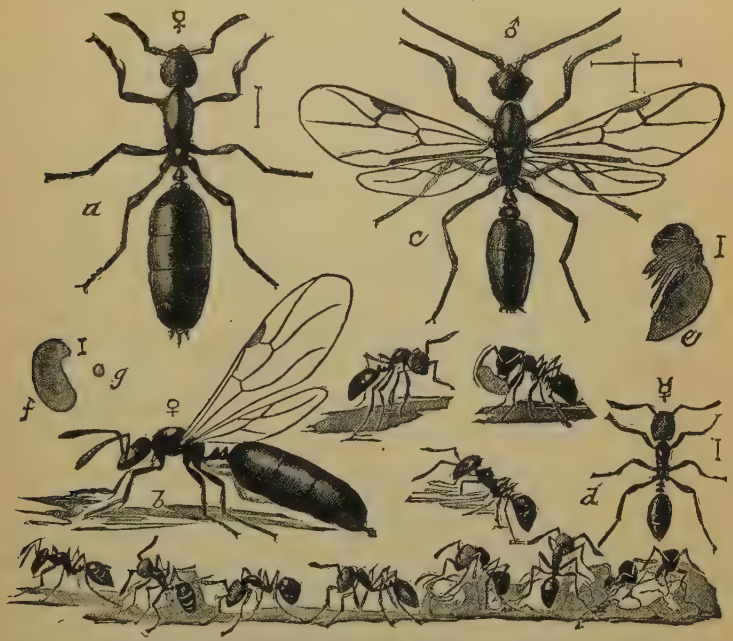


FIG. 190. — Little black ant, **Monomorium minutum**. *a*, female; *b*, same with wings; *c*, male; *d*, workers; *e*, pupa; *f*, larva; *g*, egg of worker. All enlarged. (After Howard and Marlatt, Bull. Div. Ent., U. S. Dep. Ag.)

this connection. His observations indicated that while there is an adaptation to complex conditions, they are not to be compared to the activities of human beings. They have developed certain kinds of nervous activities which no doubt parallel in some respects those of vertebrates, but are much more dependent on instinct. There are many species, among them the little red ants,

occurring in gardens, walks, etc., the house ants, and the large carpenter ants which form nests in hollow logs. The queen is quite a large insect and usually with wings entirely wanting. Large red ants and large black ants construct hills for their nests, sometimes three to six or eight inches high, and perhaps twelve to eighteen inches across the top. This red ant is a slave-making species, going out on forays and capturing black ants which are utilized to carry on the labor of the colony. Some species are said to have carried the slave-making habit to such an extreme that they are unable to get along without the slaves, and even require slaves to go out and capture new slaves.

Wasps, Sphecina. — In this group we have a considerable number of solitary forms or those which preserve the primitive condition of males and females without workers or with large broods raised at one time in one nest. Mud, paper, pith, etc., are used as building materials. The sand wasp burrows into the sand for its nest. They stock these nests with insects of different kinds, such as May flies. The larvæ develop by feeding upon the bodies of these stored insects. It appears strange that they can keep a burrow in loose sand complete enough so that they can pass in and out a number of times. They are protected to some extent by the coloration of the body. Their burrows are constructed throughout the summer, and the larvæ develop during the summer and presumably all reach the pupa stage before winter and live over as pupa, issuing the following season. The adults will be found flying around all through the midsummer months, but perhaps they are a little more abundant in the latter part of July.

The social wasps make large nests and have large colonies and show some degree of differentiation into classes or castes of individuals, in that there may be smaller individuals, apparently workers, that occur during the summer and help to care for the colony, and finally larger individuals at the end of the season which live through the winter.

The hornet builds up a large paper nest which is made up of

a series of combs with the aperture at the lower part. This becomes very populous during the latter part of the summer. The survivors are adults that secrete themselves under leaves, etc., and start a fresh colony in the succeeding year. They do not live in the large nest through the winter. This common species is social. The yellow jacket is also social, and there are some species that build mud nests, but those are mostly solitary. It is interesting to compare the materials used. They use wood or mud, or paper which is a pulp worked up from the wood fiber and is to

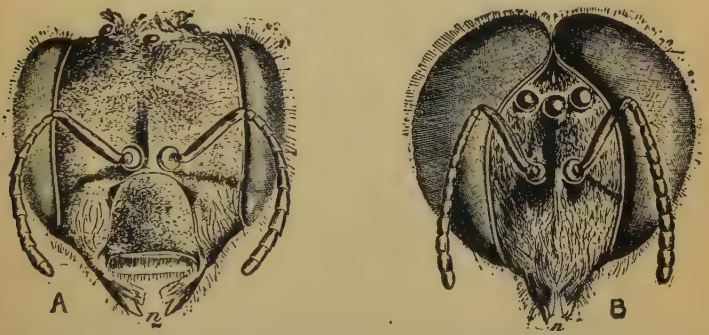


FIG. 191. — A, head of queen bee, magnified ten times, showing smaller compound eyes at sides, and three ocelli on vertex of head; *n*, jaw notch; B, head of drone, magnified ten times, showing larger compound eyes at sides, with three ocelli between; *n*, jaw notch. (From Cheshire.)

be compared to paper in the tissue of which it is made and in the manner of manipulation.

Apina. — In the bees there is an elongation of the beak for getting the nectar from the flowers; and the more specialized forms secrete wax for the formation of the cells. This is worked up into a gum or built into cells for the rearing of the larvæ. There is a gradual culmination in the development of community life in this family, from the wild bees that are practically solitary up to the bumble bee and honey bee.

The honey bee is one of the best known and most widely distributed species of insects, and on account of the value of the

honey crop certainly stands next to the silkworm in its value to man. While not so completely under our control, it may properly be considered as a domesticated insect. It has been utilized from early historic times, and doubtless the ancients were well informed concerning methods for its culture. Several varieties or races have been developed, as the German or black bee, the Italian, Carniolan, Cyprian, etc.

A bee colony consists of a queen or fertile female, which lays the eggs and is in reality the mother of the entire colony. Without a queen a colony will rapidly dwindle, and, unless her place is filled by the rearing of a new queen or introduction of a new one, must soon die out. The drones or males occur in considerable numbers, a few hundreds at most during a few weeks of the summer, at the time when young queens are developed. They are normally sexed individuals, are without stings, and take no part in the labors of the colony, but are, of course, essential in the fecundation of queens. A third form, the workers or neuters, are the most numerous, a thriving colony containing from forty to fifty thousand. They are undeveloped females, and their function

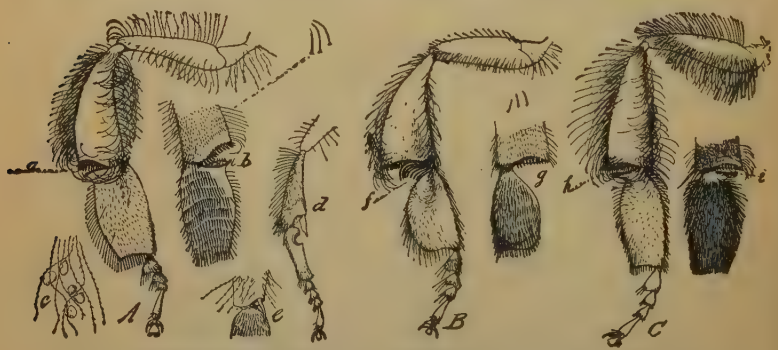


FIG. 192. — Modifications of the legs of different bees. A, **Apis**; *a*, wax pincer and outer view of hind leg; *b*, inner aspect of wax pincer and leg; *c*, compound hairs holding grains of pollen; *d*, anterior leg, showing antenna cleaner; *e*, spur on tibia of middle leg. B, **Melipona**, *f*, peculiar group of spines at apex of tibia of hind leg; *g*, inner aspect of wax pincer and first joint of tarsus. C, **Bombus**; *h*, wax pincer; *i*, inner view of same and first joint of tarsus. All enlarged. (From *Insect Life*, Div. Ent., U. S. Dep. Ag.)

in the colony is the collecting of honey, building of comb, caring for the young, and in short all the duties of the colony apart from the production of eggs. The life of the queen may extend over four or five years, during which some millions of eggs will be deposited, the great majority of which are fertilized and developed into worker bees, while a much smaller number are deposited in larger or drone cells, are unfertilized, and produce drones. The drones live but a few weeks, the workers for a few weeks in summer during their active period, but a longer period, three or four months, in winter, carrying the colony over a period when no young bees are reared. The life of the colony is therefore continuous, and by the replacement of the queen, on death or removal

FIG. 193. — Honey bee, **Apis mellifica**. *a*, queen (perfect female); *b*, worker (imperfect female); and *c*, drone (male). (After Brehm.)

by swarming, by a young queen the life of the colony is continued indefinitely, although the bees within it may be produced by entirely different parents. Eggs deposited in cells hatch within about three days; the young bees, which are footless, helpless grubs, are fed by nurse bees and developed through the larval and pupal stages in sixteen days for the queen, twenty-one days for workers, and twenty-four days for drones. The rearing of the queen is accomplished by furnishing a newly hatched egg with a richer quality of food (royal jelly) and a larger cell. The swarming of the colony is a natural provision for increase in the number of colonies and must be considered as fixed by natural selection, since without such a provision the species would necessarily become extinct, as any colony would be liable to die out, and unless there were some provision for increase in number of colonies all must ultimately disappear. This is, perhaps, one of the most

remarkable adaptations associated with the community life in the bee and one which is distinctly in advance of what occurs in the case of bumble bees, wasps, ants, and other social insects. The swarming process consists in the departure from the parent colony of the great proportion of the active bees along with the queen, their establishment in some new locality, and the building of comb, rearing of brood, and complete isolation from the original swarm. The colony from which the swarm has issued has already provided for a new queen by the rearing of a number of young queens, one of which ordinarily assumes the duties of the queen, meeting and killing other queens that may issue at about the same time. The young queen may issue from the colony for impregnation, mating occurring on the wing, and doubtless at some distance from the colony. This usually occurs during the first bright day after the emergence of the queen from the queen cell. Once fertilized, the queen never leaves the colony except to accompany a swarm, and the continued fertilization of eggs is provided for in the storage within a seminal receptacle, a sac-like enlargement of the oviduct, of spermatozoa, which are given off as eggs are extruded. Evidently the queen is able to control fertilization, so that eggs deposited in the drone cells are not fertilized. This is a rather remarkable form of parthenogenesis, and a fact which is of the utmost importance in the breeding of new strains of bees.

Honey is the most important product of the apiary, its value running up into many millions of dollars for the United States. It is essentially a stored material, being obtained as the nectar from different plants, and so little changed that the honey collected from different plants retains its characteristic taste and color in the cells. There is some evaporation of moisture, probably an addition of a slight amount of formic acid, after which the cells are sealed and the honey remains unchanged, except possibly for occasional granulation due to a crystallization of sugar. Wax, the next most important product, is a bee product, being formed by the wax glands which lie on the abdominal segments. It is

worked into comb by the bees, and the comb may be used indefinitely, but owing to the addition of extremely thin cocoons, the cells will, in the course of years, become smaller, and if used continuously for brood comb, may result in the production of a smaller size of bees. It may be noted here that while ants use earth or wood particles as architectural material, and the paper-making wasps are able to produce a manufactured product from vegetable fiber, the wax secretion is a definite product of the insect itself. Propolis, which is used as a cement for fastening comb to the frames or to the walls of the cavity in which the colony resides in nature, is collected from the buds of certain trees, and bee bread, which is largely the food provided for the larvæ, is simply the pollen of various flowers.

Aside from the great importance of the honey industry, bees occupy a most important relation to man and to the success of

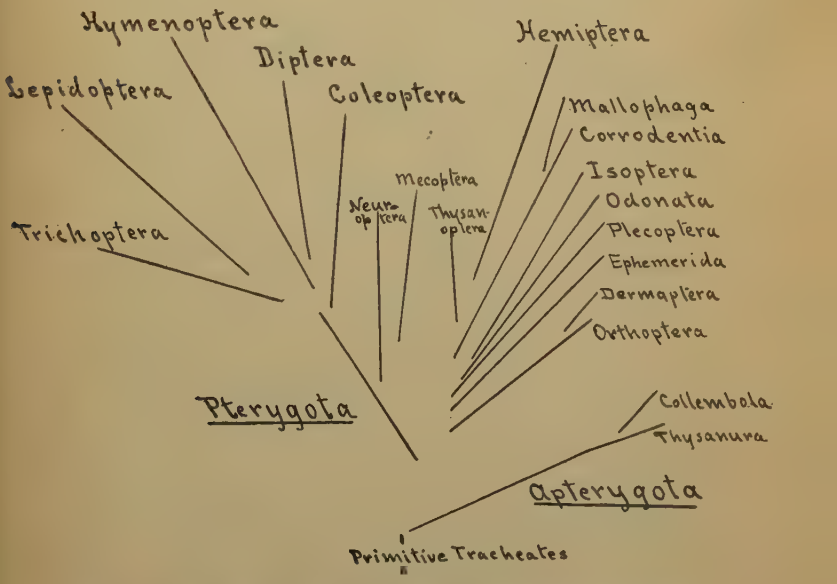


FIG. 194. — Diagram to illustrate the affinities of the **Insecta** (original).

many plants in their office as pollinators, since their trips from flower to flower, distributing pollen, provide a means, in some cases an essential means, for the cross fertilization of bloom. Methods of apiculture have developed into an extended art and are treated at length in many special works, and cannot of course be taken up in detail in this connection.

CHAPTER XIV

CHORDATA

We now come to a series of animals in which the fundamental plan of structure consists of a central axial rod or chordal axis, which in the higher forms develops into a vertebral column and which separates the body into a dorsal or neural portion and a ventral or hæmal portion, the former including the nervous system and the latter the visceral organs, such as the alimentary, circulatory, and excretory systems. Inasmuch as the most important groups in this section are the forms possessing a well-defined backbone, the general characters of which will be discussed under Vertebrata, we will take up for consideration in this connection only some minor divisions in which the essential chordate plan of structure is present in a much less perfect condition.

Hemichorda

Grouped under this division we will consider a few quite primitive forms of animals in which the beginning of the chordal axis seems to be indicated and in which the essential relation of parts in the body is upon the chordate plan.

In general character these forms possess an elongate body more or less twisted and irregular but essentially bilaterally symmetrical and showing three distinct regions, — the anterior preoral region or proboscis, the central or collar region immediately behind the mouth, and a trunk region the anterior part of which possesses a number of dorsal gill slits. The nerve cords extend along the dorsal and ventral wall of the body lying above and below the alimentary canal. Connected with the anterior part of this canal

is a small pouch-like structure extending forward into the proboscis and constituting the base of support for this structure. This organ in its origin and position corresponds essentially with the notochord of amphioxus or the larval tunicate, but it does not develop posteriorly to form a complete axial rod for the support of the entire body.

The *Balanoglossus*. — The most common member of this group is a small, worm-like creature occurring in shallow waters of the ocean at widely separated localities. The proboscis is long and at its base there is a small mouth opening followed by a distinct collar. The mouth is succeeded by a narrow pharynx, and this is divided into a dorsal portion which is connected with the branchial slits and provides for respiration, and a ventral portion through which the food material is carried on into the stomach. In development the Balanoglossus passes through stages which correspond to the blastula and gastrula of other groups, and there is in most species a distinct larval form called the tornaria, which suggests the larval form of annelids, or mollusks, or certain stages of the echinoderms.

Related to the Balanoglossus is a peculiar marine animal known as Cephalodiscus, which possesses a number of characters that seem to show a remote relationship to the Balanoglossus, but which probably have been greatly modified as a result of their sedentary conditions.

Rhapdopleura, another form, also attached and occurring in colonies, shows in the struc-

FIG. 195. — **Balanoglossus**. Entire animal. *br*, branchial region; *co*, collar; *gen*, genital ridges; *hep*, prominences formed by hepatic cæca; *pr*, proboscis. (After Spengel.)

ture of the mouth the presence of a primitive notochord and in the distribution of the body cavities a relationship to these groups, but it is evidently more degenerate.

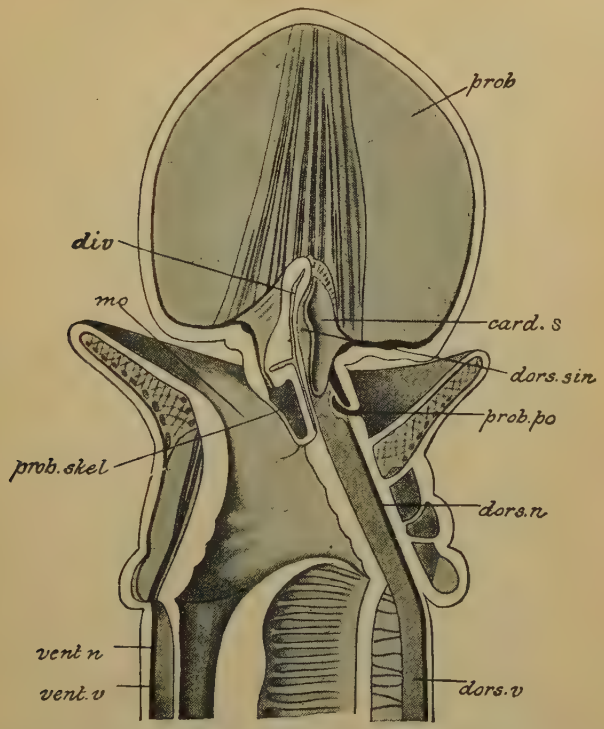


FIG. 196. — **Balanoglossus.** Diagrammatic sagittal section of anterior end. *card.s*, cardiac sac; *div*, diverticulum (supposed notochord); *dors.n*, dorsal nerve strand; *dors.sin*, dorsal sinus; *dors.v*, dorsal vessel; *mo*, mouth; *prob*, proboscis; *prob.po*, proboscis pore; *prob.skel*, proboscis skeleton; *vent.n*, ventral nerve strand; *vent.v*, ventral vessel. (After Spengel.)

UROCHORDA OR TUNICATA

The tunicates are rather aberrant animals, and their relationship has been but poorly fixed until recent years, since they depart very distinctly in their adult stages from any of the groups of

animals to which they are related. Since their development has been traced, it has been recognized that they are related to the animals having the chordal axis, as a notochord appears during

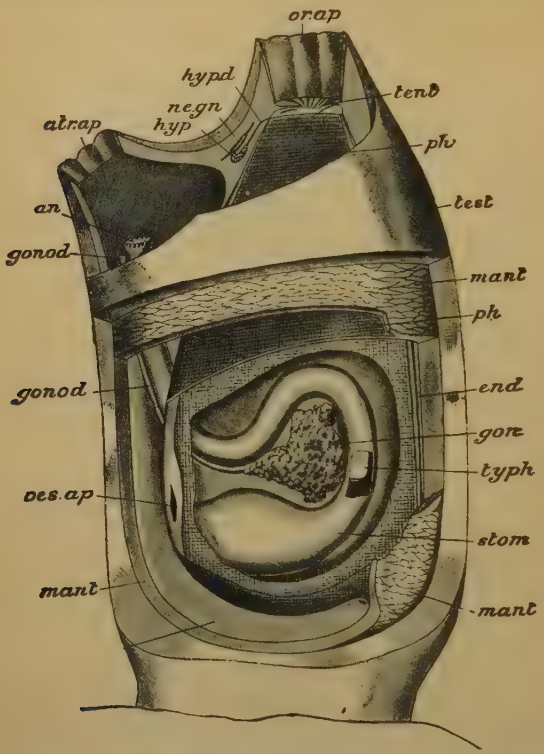


FIG. 197. — Dissection of **Ascidia** from the right-hand side. The greater part of the test and mantle has been removed from that side so as to bring into view the relations of these layers and of the internal cavities and the course of the alimentary canal, etc. *an*, anus; *atr.ap*, atrial aperture; *end*, endostyle; *gon*, gonad; *gonod*, gonoduct; *hyp*, hypophysis; *hyp.d*, duct of hypophysis; *mant*, mantle; *ne.gn*, nerve ganglion; *œs.ap*, aperture of esophagus; *or.ap*, oral aperture; *ph*, pharynx; *stom*, stomach; *tent*, tentacles; *test*, test. (After Herdman.)

the early stages of development, but in nearly all of the different species becomes entirely lost before they reach maturity.

Most of the species in the group are sedentary forms which have lost almost all of the symmetry which is present in the early stages, and they show simply an adaptation to the fixed habit. They are known as "sea-squirts" from the fact that a jet of water is ejected from them when they are disturbed or if they are pressed in the hand. A considerable number of different forms occur,

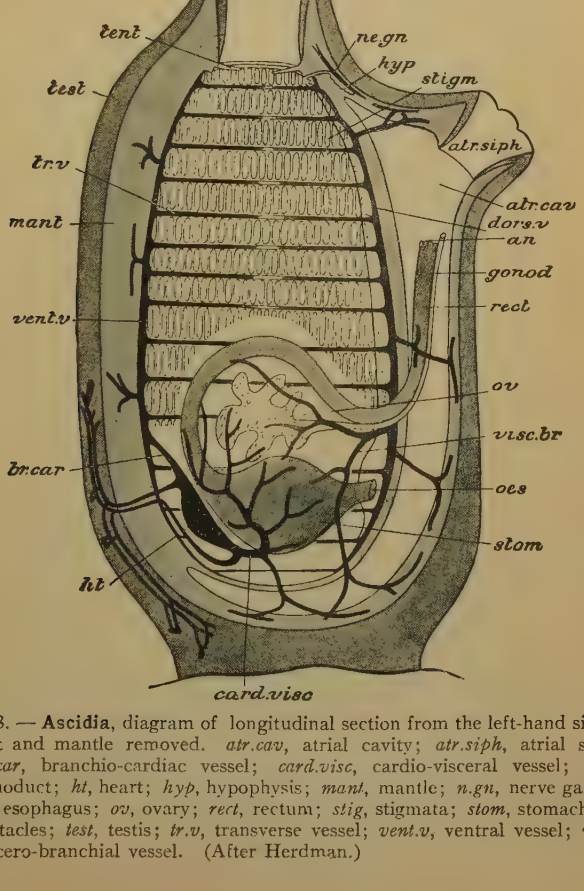


FIG. 198. — **Ascidia**, diagram of longitudinal section from the left-hand side, the test and mantle removed. *atr.cav*, atrial cavity; *atr.siph*, atrial siphon; *br.car*, branchio-cardiac vessel; *card.visc*, cardio-visceral vessel; *gonod*, gonoduct; *ht*, heart; *hyp*, hypophysis; *mant*, mantle; *n.gn*, nerve ganglion; *œs*, esophagus; *ov*, ovary; *rect*, rectum; *stig*, stigmata; *stom*, stomach; *tent*, tentacles; *test*, testis; *tr.v*, transverse vessel; *vent.v*, ventral vessel; *visc.br*, viscero-branchial vessel. (After Herdman.)

but we may consider the common Molgula as a representative form. In this species there are opposite the attached base two openings in the body wall, the first one corresponding to the mouth and the other forming the atrial opening. The outer wall, or tunic, forms a protecting covering for the animals, and must be cut open in order to observe the body proper. The pharyngeal part of the alimentary canal is much expanded, and possesses a large number of slits, forming what is called the branchial basket. Water taken into the branchial cavity passes out through these branchial openings over the capillaries of the blood system and accomplishes respiration. From the branchial basket there is a slender, short esophagus which expands into a large stomach occupying a considerable portion of the body cavity. The stomach bends abruptly and contracts into a slender intestine which opens into the atrial chamber near the atriopore. Water for respiration enters the mouth, passes through the branchial slits into the atrial chamber, and out through the atriopore.

The circulatory system consists of a pulsating blood vessel lying on the ventral side of the pharynx which may be doubtfully considered as homologous with the heart in other vertebrates. A peculiarity in the blood movement is that it flows in one direction for a time, and then reverses and flows in the opposite direction. The excretory system is represented in an organ attached to the intestine, and is quite degenerate as compared with the nephridial organs of the vertebrates. The nervous system is much reduced. The principal ganglion lies on the dorsal side of the esophagus, and from this ganglion nerve fibers extend forward and backward. There is a median eye and an auditory organ present in the larval stage, but these become entirely lost in the adults. The reproductive organs of both sexes occur in the same individual, and consist of simple genital glands, the ovary being the larger and connected with a cavity which receives the eggs as they are discharged from the ovaries. The testes surround the ovaries; and the periods of maturity in these are different from that of the ovaries, so that self-fertilization is avoided.

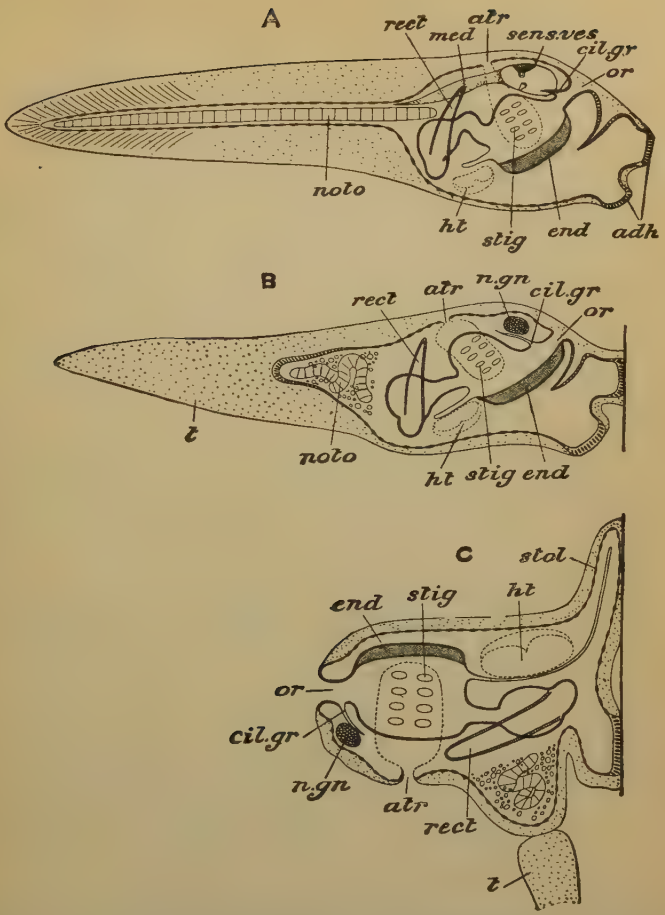


FIG. 199. — Diagram of the metamorphosis of the free, tailed larva into the fixed Ascidian. A, stage of free-swimming larva; B, larva recently fixed; C, older fixed stage. *adh*, adhesive papillæ; *atr*, atrial cavity; *cil.gr*, ciliated groove; *end*, endostyle; *ht*, heart; *med*, ganglion of trunk; *n.gn*, nerve ganglion; *noto*, notochord; *or*, oral aperture; *rect*, rectum; *sens.ves*, sense vesicle; *stig*, stigmata; *stol*, stolon; *t*, tail. (From Korschelt and Heider, after Seeliger.)

Fertilization is supposed to occur in the cloaca. In development there is complete segmentation and the formation of blastula. The development is of special interest, however, since after a short period, called the "tadpole" stage, in which the larva resembles a young vertebrate, and possesses a well-developed notochord, there follows an extreme specialization, with an alternation of form and degeneration of structure. This occurs as a result of the attachment of the larva by the head end and further development of the mouth and adaptation of the stomach to the altered position, resulting in a very distinct distortion of the primitive structure.

While these processes of development and the extreme degeneration of some structures, especially the notochord and locomotor organs, must be considered as resulting from the sedentary habit, and while most of the tunicates remain fixed throughout life and even multiply by budding, there are a few forms which seem to have broken away from the sedentary condition and adapted themselves to free swimming. These, however, still show the effect of the sedentary habit, their symmetry being entirely distinct from that of the larval form.

The tunicates may therefore be looked upon as a group which started out with primitive ancestral forms of vertebrates, but which, on account of changing to a sedentary habit, has lost entirely the features pertaining to the vertebrates, and whose relationship to the vertebrates is now to be learned only by a study of the early stages in which certain vertebrate characters persist.

From an economic standpoint the tunicates are of comparatively little importance. They are distinctly marine in their habits, and occur attached to rocks or submerged objects except for the few forms which are free swimming; and while they constitute some small factor in the food supply of other marine animals, they cannot be considered as of especial importance in this direction. They do not enter into commerce as food material or in any connection except as museum specimens, and little or no use is made of them for any practical purpose. They are taken advantage of by certain other animals, which find convenient habi-

tation within the tunic, some species of aquatic and marine animals making their home very constantly within this protection. Some of the more complex species become colonial in habit, and a number of individuals collect together and show a certain amount of dependence upon each other.

Cephalochorda

Cephalochorda. — This group, which includes the lancelet, or *Amphioxus* (the technical name being almost as familiar as the common one), embraces a small group of animals which are distinctly more primitive in structure than the fishes, since there is no separation of the head region or segmentation of the chordal axis, and there is a very primitive condition of the central nervous system.

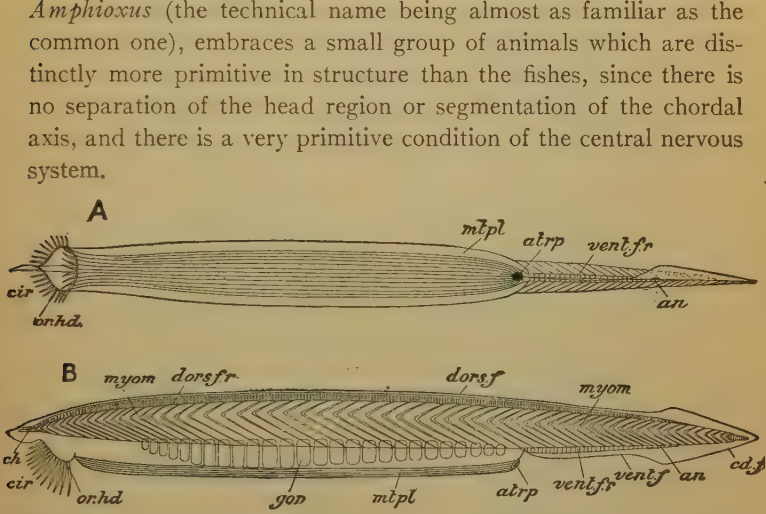
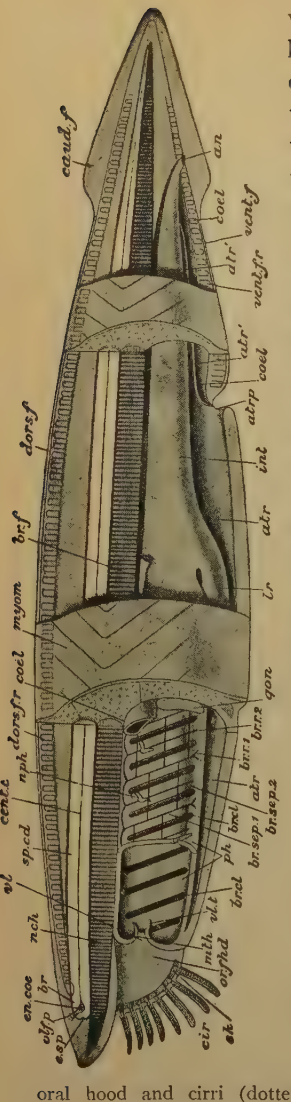


FIG. 200. — **Amphioxus lanceolatus**. A, ventral; B, side view of the entire animal. *an*, anus; *atrp*, atriopore; *cd.f*, caudal fin; *cir*, cirri; *dors.f*, dorsal fin; *dors.f.r*, dorsal fin rays; *gon*, gonads; *mtpl*, metapleure; *myom*, myomeres; *nch*, notochord; *or.hd*, oral hood; *vent.f*, ventral fin; *vent.f.r*, ventral fin rays. (After Kirkaldy.)

The amphioxus is common along the Atlantic coast from Chesapeake Bay southward to Florida, and lives in sand in shallow waters, occasionally swimming freely in the water. Sometimes a number are grouped in a slender line and move together with a snake-like movement. The body is lance-shaped, flattened vertically, and there is a thin dorsal or caudal fin consisting simply of an extension of the skin. There are no traces of fins or other organs



which correspond to the legs of higher vertebrates. The lateral fold on either side incloses a furrow along the ventral line from the mouth to the anal aperture. The mouth is on the ventral side close to the anterior end, and is surrounded by a circle of tentacles whose office is to pass currents of water into the mouth cavity. There are no jaws, the mouth opening into an esophagus, and this expanding into a stomach, the posterior part of which is the functional digestive tract and which terminates through a short intestine and anal opening located at about three fourths the distance from the head end. The anterior portion of the esophagus is expanded into a branchial cavity, along the side of which are numerous gill slits, permitting the passage of the water into an atrial chamber surrounding the alimentary canal, and

FIG. 201. — Diagram of the anatomy of **Amphioxus**. *an*, anus; *atr*, atrium; *atr'*, its posterior prolongation; *atrp*, atriopore; *br*, brain; *br.cl*, branchial clefts; *br.f*, brown funnel; *br.sep. 1*, primary, *br.sep. 2*, secondary, branchial lamellæ; *br.r. 1*, primary, *br.r. 2*, secondary, branchial rods; *caud.f*, caudal fin; *cent.c*, central canal; *cir*, cirri; *cœl*, cœlom; *dors.f*, dorsal fin; *dors.fr*, dorsal fin ray; *encœ*, encephalocœle; *e.sp*, eye spot; *gon*, gonad; *int*, intestine; *lr*, liver; *mth*, mouth; *myom*, myomeres; *nch*, notochord; *nph*, nephridia; *olf.p*, olfactory pit; *or.f.hd*, oral hood; *ph*, pharynx; *sk*, skeleton of oral hood and cirri (dotted); *sp.cd*, spinal cord; *vent.f*, ventral fin; *vent.f.r*, ventral fin ray; *vel*, velum; *vl.t*, velar tentacles.

opening externally by an atriopore just in front of the anal opening.

The skeleton is represented by the chordal axis, or simple notochord, which lies directly below the nerve cord, and forms an axis of support for the body. In addition to this there are a number of chitinoid bars supporting the gill slits, and in the anterior part there is a ring-like structure surrounding the mouth opening. The sheath of the notochord extends dorsally and includes the nerve cord, and supports or furnishes attachment for the myotomes, or muscle segments. These myotomes are about sixty in number, and form a lateral muscle wall of the body, being divided into a dorsal and ventral portion, which form a distinct

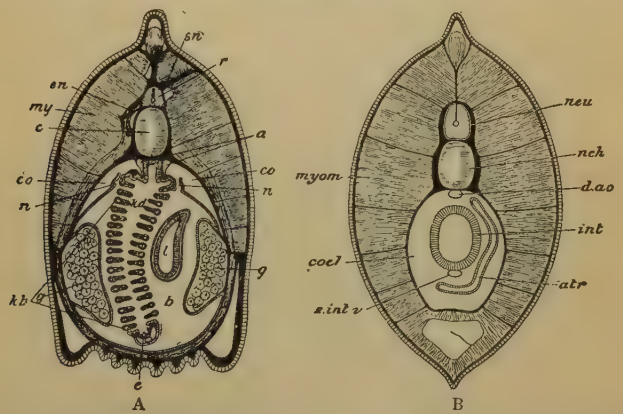


FIG. 202. — **Amphioxus lanceolatus.** A, transverse section of the pharyngeal region. *a*, dorsal aorta; *b*, atrium; *c*, notochord; *co*, cœlom; *e*, endostyle; *g*, gonad; *kb*, branchial lamellæ; *kd*, pharynx; *l*, liver; *my*, myomere; *n*, nephridium; *r*, neuron or dorsal nerve tube; *sn*, spinal nerves; *sp*, gill slits. B, transverse section of the intestinal region; *atr*, atrium; *cœl*, cœlom; *d.ao*, dorsal aorta; *int*, intestine; *myom*, myomere; *nch*, notochord; *neu*, neuron; *s.int.v*, subintestinal vein. (A, from Hertwig, after Lankester and Boveri; B, partly after Rolph.)

angle with each other, the angles making a distinct line on the side of the body. The movements of these muscles provide for a lashing motion of the tail, which serves to propel the animal forward. The muscle fibers are for the most part striated.

The nerve cord lies just above the notochord, and forms an elongate tube, the anterior part of which is slightly widened, although it does not form a distinct brain. It opens externally by a small pore in the larva, the neuropore. Two sets of nerves are given off along the neural cord, one dorsal and the other ventral, and except for the first two in the head region they correspond in number and disposition to the myotomes. These nerves are considered as corresponding to the dorsal and ventral or the sensory and motor roots of the spinal nerves among the higher vertebrates. The dorsal fibers, however, are distributed in part to muscles as well as to the skin, and lack the ganglionic enlargement which is characteristic of the dorsal root in higher forms. Circulation consists in the forcing of blood from a ventral vessel through the branchial blood vessels, and the collection of the blood from these into a dorsal vessel which runs backward, giving off smaller arteries which break up into capillaries in the

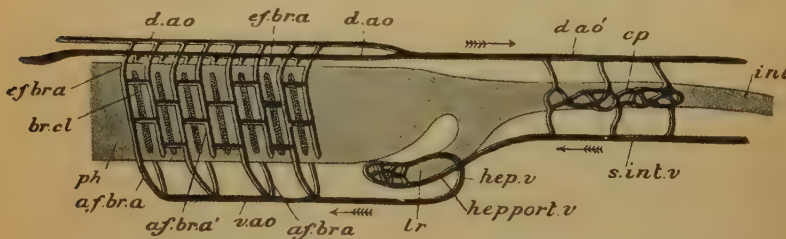


FIG. 203. — Diagram of the vascular system of **Amphioxus**. *af.br.a*, afferent branchial arteries; *cp*, intestinal capillaries; *d.ao*, paired dorsal aortæ; *d.ao'*, medial dorsal aorta; *ef.br.a*, efferent branchial arteries; *hep.port.v*, hepatic portal vein; *hep.v*, hepatic vein; *int*, intestine; *lr*, liver; *ph*, pharynx; *s.int.v*, subintestinal vein. (After Parker and Haswell.)

various parts of the body, and reuniting into veins that connect with the ventral vessel. The general plan, therefore, is essentially that of the vertebrates. Excretory organs are supposed to be represented in a series of minute nephridia lying in a dorsolateral portion of the atrium. The sexual organs are simple, without ducts, and form a series of genital sacs projecting into the atrial cavity. Their contents are discharged into the atrial

cavity, and pass out by the atriopore. Fertilization takes place in the adjacent water. The development is simple and is a good example of the process of holoblastic segmentation, the fertilized ova dividing completely, and successive divisions being nearly equal until a very perfect blastula is formed. At this stage,

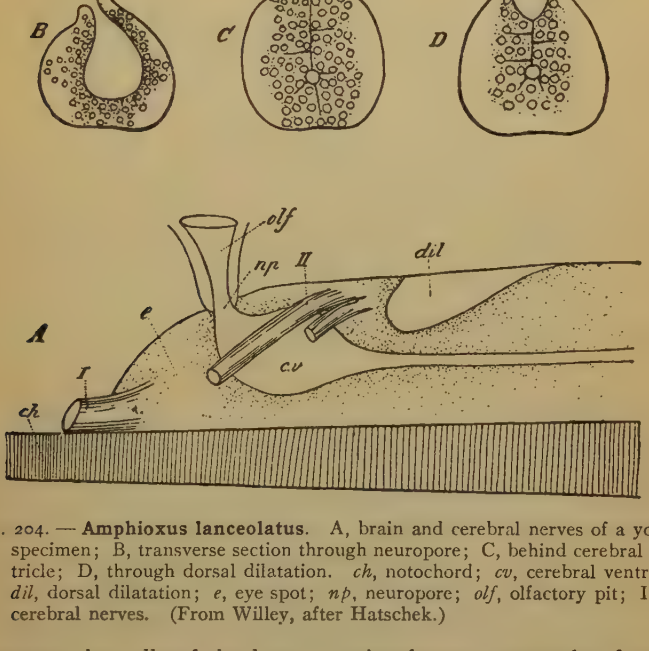


FIG. 204. — **Amphioxus lanceolatus**. A, brain and cerebral nerves of a young specimen; B, transverse section through neuropore; C, behind cerebral ventricle; D, through dorsal dilatation. *ch*, notochord; *cv*, cerebral ventricle; *dil*, dorsal dilatation; *e*, eye spot; *np*, neuropore; *olf*, olfactory pit; I, II, cerebral nerves. (From Willey, after Hatschek.)

however, the cells of the lower portion become somewhat larger, and this part invaginates to form a gastrula. During the gastrula stage the dorsal cells begin to invaginate to form a neural canal, and this canal remains open posteriorly or connects with the archenteron to form the neurenteric canal, while anteriorly it remains open during larval life as the anterior neuropore. The archenteron forms the midgut, and the invaginations of the stomodæum and proctodæum complete the alimentary canal. The early larval

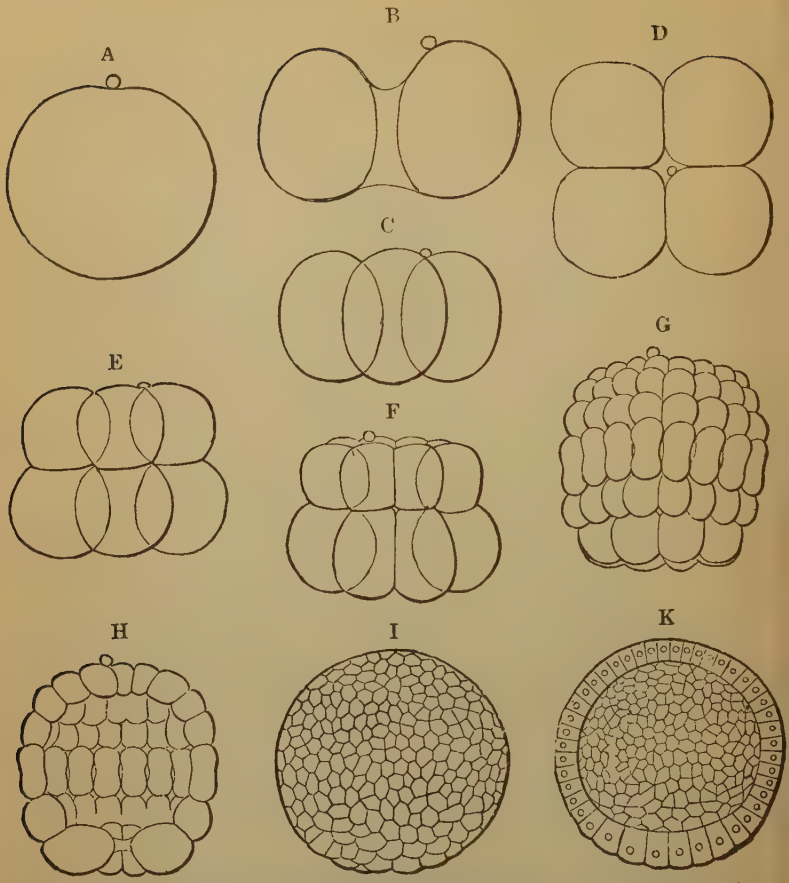


FIG. 205. — **Amphioxus lanceolatus**. Segmentation of the oosperm. D, the four-celled stage, C, from above; H, vertical section of G; K, vertical section of the blastula stage I. (From Korschelt and Heider, after Hatschek.)

stage is active, but later becomes fixed, and is for a time distinctly asymmetrical, but by further development the more complete symmetry of the adult is reached.

Amphioxus is of especial interest, since it appears to stand as the most primitive existing form possessing the most generalized

structure of the vertebrates. While, no doubt, it is somewhat divergent, or has degenerated, it has not lost its primitive structure in any such degree as is shown in the tunicates; and in the presence of the chordal axis with its relation to the nerve cord, circulatory systems, alimentary tract, and in the beginning of the differentiation in the nerve cord to form a brain and spinal cord, as well as in the branchial slits, there is close agreement with the fundamental plan of vertebrate structure. Inasmuch as the chordal axis is not segmented, and therefore not strictly like the

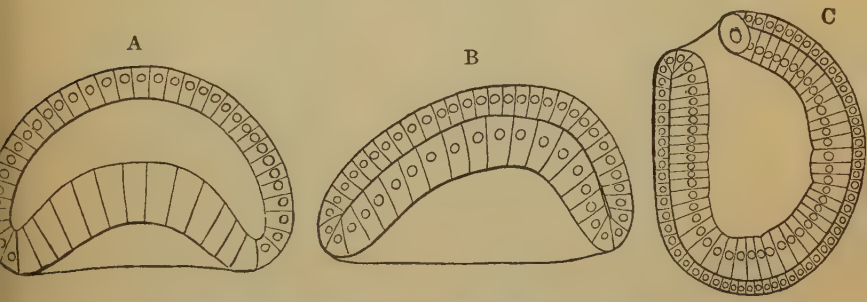


FIG. 206. — **Amphioxus lanceolatus.** Three stages in the formation of the gastrula. (From Korschelt and Heider, after Hatschek.)

vertebrates, it is more satisfactory to consider the group as belonging to a general division, the Chordata, in which the presence of a chordal axis stands as a typical character. It should be noted that the formation of the myotomes, or the muscle segments, is here well marked, and that they precede the segmentation of the chordal axis. This is in strict harmony with the course of development of the vertebrates, where the development of muscle segments precedes the formation of the vertebræ. It is evident, therefore, that the formation of the vertebræ or the segmentation of the hard axial skeleton is an adjustment to the muscle segments, and not preceding or determining the segmentation of the muscles. Considered as a basis for the vertebrate group, amphioxus should be looked upon simply as a persistent type which probably represents most closely the characters of a primitive

form, from which the higher vertebrates were developed. It is easy to see that the higher forms have traveled an immense distance beyond these simple and generalized forms.

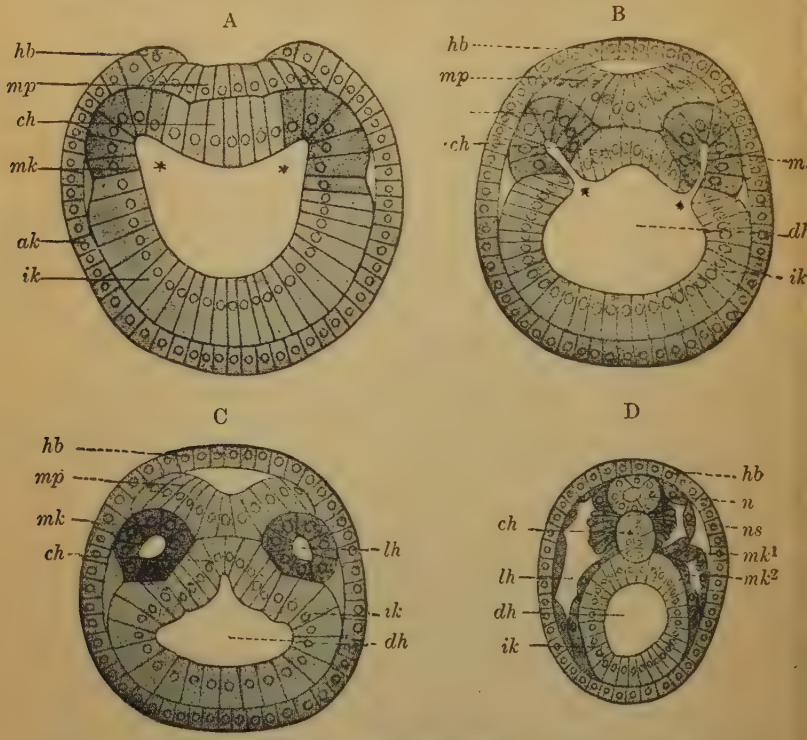


FIG. 207. — **Amphioxus lanceolatus.** Four stages in the development of the notochord, nervous system, and mesoderm. *ak*, ectoderm; *ch*, notochord; *dh*, cavity of archenteron; *hb*, ridge of ectoderm growing over medullary plate; *ik*, endoderm; *lh*, cœlome; *mk*, cœlomic pouch; mk^1, parietal layer of mesoderm; mk^2, visceral layer; *mp*, medullary plate; *n*, nerve tube; *ns*, protovertebra. (From Korschelt and Heider, after Hatschek.)

In looking in the other direction, the amphioxus shows relation to the tunicates in the presence of its chordal axis, and may be considered as having retained much of its general structure, while the tunicates have, by a long process of retrogression, lost quite

completely the chordal axis and the condition of body which was associated with these structures. The relationship of the two groups is now to be determined only by comparison of the larval stages of the tunicates and amphioxus. Aside from the interest

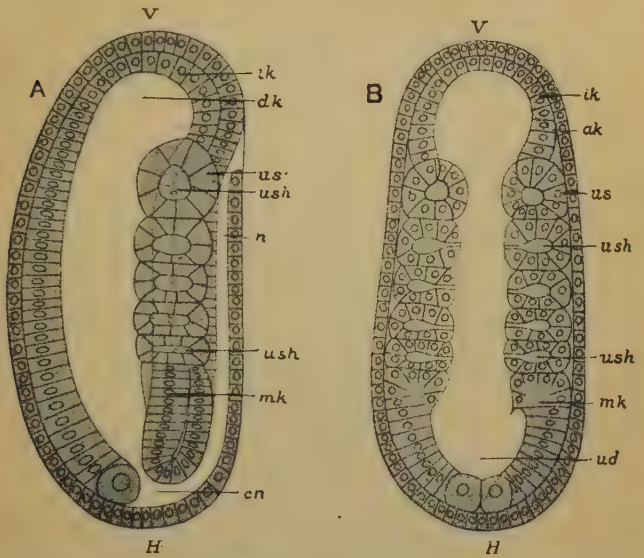


FIG. 208. — **Amphioxus lanceolatus.** Embryo. A, from the side; B, in horizontal section. *ak*, ectoderm; *cn*, neurenteric canal; *dh*, archenteron; *us*, first cœlomic pouch; *ush*, cœlomic cavity; V, anterior, H, posterior, ends. (From Korschelt and Heider, after Hatschek.)

that attaches to these animals in connection with their relationship to the vertebrates, they are of but little importance, as they are too few in numbers to have any particular influence on aquatic life. The group must have been represented during a long period of the earth's history, but since all the parts are soft and easily disintegrated, they could not be expected to occur in fossils, and therefore the early history of the group is unknown.

CHAPTER XV

VERTEBRATA

The vertebrates in the sense generally used include those animals which have a backbone composed of vertebræ, and in which the nerve cord lies dorsal to the axis of the vertebral column, while the alimentary canal lies ventral to it. The group includes most of the larger land animals, as well as the fishes and amphibians and some other aquatic forms. The essential characters common to the group at large are the segmented vertebral column, the vertebræ having various forms in different groups, and in most cases being provided with processes which extend upward and downward from the central body. The primitive vertebra possesses, however, a central body, or **centrum**, and an arch both above and below, the former called the **neural arch**, composed of two processes extending dorsally and uniting above in a spinous process and including the space through which the nerve cord passes. The lower or **hæmal arch** extends similarly downward, and unites in a hæmal spine. The nerve cord lies in the neural canal dorsal to the chordal axis, and anteriorly forms a brain inclosed in most groups in a distinct bony cranium, while the remainder, the spinal cord, extends back to near the end of the vertebræ. Lateral nerves are given off that correspond to the vertebræ in number, and supply the body segments. Cranial nerves arise from the brain, and supply the senses of smell, sight, hearing, touch, and taste, and also contain the motor nerves, which are associated with the head segments. Each segment of the brain consists of a right and a left portion, and possesses as main divisions the **cerebrum**, the **optic thalami**, the **optic lobes**, the **cerebellum**, and the **medulla oblongata**.

As a result of the method of origin of the nervous system, it is essentially a tubular structure, the anterior part of which is expanded to form the divisions of the brain. It arises by the infolding of the ectoderm along the dorsal line, and is formed by the layers coming together and fusing so that the neural tube is a cylindrical, elongate structure lying directly above the chordal axis. The brain region is divided primarily into three vesicles, which are the embryonic **fore-**, **mid-**, and **hind-brain**, and these primary brain vesicles further divide, so that the anterior one forms two lobes and the posterior one two, thus giving five divisions. The most anterior is called the **prosencephalon**, and the second **thalamencephalon**, these two derived from the fore vesicle. The central or mid vesicle forms the optic lobe, or **mesencephalon**, while the hind vesicle forms the **metencephalon**, which is the cerebellum, and the **myelencephalon**, or medulla oblongata.

In the origin of the nerves from these parts of the brain there is a certain amount of indication of the primitive segments, for sensory and motor structures are both represented, but these are not associated so that sensory nerves always accompany the motor nerves, but one or the other have in some parts evidently been suppressed, and it is difficult to determine certainly the homologies or connections of the different cranial nerves. Ten pairs are recognized as distinctly cranial. The first is the **olfactory**, supplying the olfactory sense and passing to the olfactory lobes. The second is the **optic**, supplying the eyes and extending to the optic lobe. The third is the **oculomotor**, supplying four of the eye muscles, and the fourth the **pathetic** or **trochlear**, supplying the superior oblique eye muscle. The fifth, the **trigeminal**, supplies both motor and sensory nerves to the facial region. The sixth, the **abducens**, supplies the external rectus of the eye. The seventh, the **facial**, both sensory and motor, is distributed to the lower part of the face and mouth. The eighth is the **auditory**, which is the sensory nerve going to the ear, and providing mainly for the sense of hearing. The ninth, the **glossopharyngeal**, includes both sensory and motor fibers, and is distributed to one of the

gill arches; and the tenth, the **vagus**, the termination of which is in the posterior gills and also the thorax.

The third, fourth, and sixth are called somatic motor nerves, since they supply the body-wall muscles. The motor portions of the remaining cranial nerves are spoken of as **visceral motor**, since they supply muscles derived from the visceral wall, such as the mandibular, hyoid, and gill muscles. The sensory fibers in the fifth, seventh, eighth, ninth, and tenth nerves fall into three classes: first, those supplying the skin, serving a tactile function, and usually called the **general cutaneous** system; second, those supplying the ear and lateral line organs, and called the **acustico-lateralis** system; third, those supplying the mucous surfaces of the alimentary canal and taste buds, wherever found, and called the **communis** system. The distribution of these various systems or **components** among the cranial nerves is exceedingly variable, even among the fishes, where they are best known. The brain centers and ganglia are, however, much more constant.

Tissues

Since with this group of animals we reach the forms in which there is a definite skeleton, composed, in most cases, of bone tissue consisting of definite bone cells, and as this completes the series of different kinds of tissues which are to be met with in the animal kingdom, it will be in place to review the various kinds of tissues and mention the functions with which they are particularly concerned. The surface of the body and certain of the internal body spaces are provided with a layer of cells termed the **epithelial** cells. These have a cuboidal, cylindrical, or sometimes flattened shape, and in some parts are provided with cilia, which in such locations as the mouth or air passages serve to carry foreign substances toward the mouth opening. For the body surface in general they compose the epidermal layer, which is modified in different forms among the different groups.

Muscular tissue, which is found in all forms of animals from the cœlenterates onward, and is represented in the muscle fiber

of such protozoans as vorticella, is the essential basis for movement in animals. It consists of muscle cells which are much elongated, and which in the simpler form are non-striated, but which in the more specialized condition present minute cross striations, these appearing in the voluntary muscles of many groups of animals, particularly the vertebrates and insects. The minute striæ represent minute sarcode elements, the simultaneous contraction of which serves to give a very rapid and extended movement of the parts to which the muscle fibers are attached. The cells or fibers combine into fascicles, and these into larger strands, which group together in larger masses and are spoken of as muscles. These usually terminate in the tendons which are attached to the hard parts of the body. They are controlled by impulses from the nervous system which are distributed by minute nerve endings terminating on the muscle cells.

Nerve tissue is represented in all groups from the cœlenterates onward, being found in the simplest form in the neuromuscular cells of Hydra and related forms. In the higher forms, however, a definite separation of nerve tissue from the epithelial cells is accomplished, and the nerve cells carried within the surface, usually to considerable depth, connection between the central nerve ganglia and the surface being made by delicate strands of nerve fibers, the central axes of which are continuations of the protoplasmic content of the ganglionic nerve cells. The nerve cells may have one or a number of such fibers, and by these be connected to other nerve cells, or to sensory organs at the surface of the body, or with muscle fibers which are stimulated by impulses from them. In the more specialized condition, nerve cells are collected into central ganglia which control all portions of the body, such special aggregations being termed the **brain** and **cord**, and reaching their highest development in the vertebrates, where the brain is inclosed within a special bony structure, the **cranium**. The special sensory organs concerned with sight, hearing, smell, taste, and touch are referred to in connection with the different groups.

Connective tissue embraces a number of quite distinct forms, such as the **gelatinous** tissue, which connects or serves as a matrix for the organs of many lower groups; **fibrous** tissue, which enters into the tendons, ligaments, and other structures, in some instances being elastic and in others rigid; **cartilage**, a firm tissue composed of distinct cartilage cells imbedded in a matrix secreted from these cells and giving rigidity or firmness to parts of the body, especially for the skeleton among the lower vertebrates and for portions of the skeleton in the higher vertebrates.

Bone tissue, or **osseous** tissue, is a distinct variety of connective tissue, the bone cells secreting a deposit of lime phosphate and carbonate, chiefly in definite layers or laminæ, these being arranged in certain bones concentrically around each bone cell and adapted to the blood vessels. In the dead bone the space formerly occupied by the cell proper is termed the **lacuna**, and from this radiate delicate tubes, **canaliculi**, once serving as channels for the cell processes and consequently for the passage of the nutritive fluids and waste products. The channels occupied by the blood vessels are termed **Haversian canals**.

In their special modification in different groups of animals, these tissues show great diversity, as the development of scales, hair, feathers, horny tissue, nails, claws, and teeth from the epidermal and dermal structures; the various kinds of glands from the epithelial and endodermal tissues of the alimentary tract; sebaceous and milk glands in the skin; bone structures, in the skin as well as the internal skeleton of the vertebrates.

In derivation these tissues show a distinct origin from particular embryonic layers, the epithelial tissues, nerve tissue, and such of the glands as are derived from the ectoderm all coming from the primitive ectodermal layer. The endoderm gives rise to the lining of the alimentary tract, and secondarily to the mesoderm, from which develop the various connective tissues, cartilage, osseous tissue, muscle, etc., which constitute the greater part of the body.

Class Cyclostomata

The members of this group are fish-like, elongate, slender animals without any jaws, but having a sucker-like mouth provided with numerous horny epidermal teeth. They occur in both salt and fresh water, but the more common condition is for them to ascend fresh-water streams at certain seasons of the year for spawning, and for the young to develop in these localities. A few, however, have become adapted entirely to fresh-water existence, probably through being isolated by changes in the drainage systems, so that they were cut off from the usual lines of communication with the ocean.

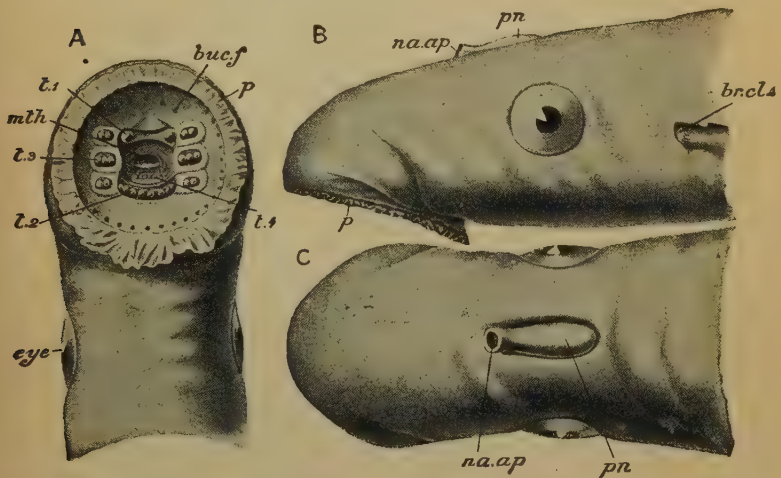


Fig. 209. — **Petromyzon marinus.** Ventral (A), lateral (B), and dorsal (C) views of the head. *br.cl. 1*, first gill cleft; *buc.f*, buccal funnel; *eye*, eye; *mth*, mouth; *na.ap*, nasal aperture; *p*, papillæ; *pn*, pineal area; *t. 1*, *t. 2*, *t. 3*, teeth of buccal funnel; *t. 4*, teeth of tongue. (After W. K. Parker.)

Our common fresh-water lamprey may be taken as an example of the group. In this species the surface of the body is soft and slimy, the mouth large and somewhat ventral and provided with several rows of sharp conical teeth adapted especially for rasping

away the tissues on the sides of fishes to which they attach themselves in order to secure food. The single nostril is median in position, and indicated by a slight elevation, and communicates with the nasal cavity, but there is no communication with the oral cavity. The eyes in the larval form are covered with skin, and probably are unable to detect images, but in the adults they are provided with a transparent cornea, and vision is doubtless much more perfect. On the side of the head are other openings which communicate with the branchial system of which they are the outlet.

The alimentary canal expands just back of the mouth cavity into the pharynx, and the esophagus, stomach, and intestine are nearly straight and simple, there being no very marked expansion for the stomach. In adults the intestine becomes reduced, and the gall bladder and bile duct disappear. From the floor of the mouth cavity there is a small opening into the branchial sac which lies underneath the esophagus. From this sac there are lateral ducts leading into the branchial pouches, from which ducts extend to the external apertures along the side of the head. Respiration is accomplished by the flow of water through the mouth and into the branchial sac and outward through the branchial pouches, where it bathes the gills. It then passes through the external openings at the side of the head. In the adult form, however, when the animal is attached to a host, the currents of water may be in and out of the lateral openings instead of through the mouth, the valves of the lateral openings being modified so that the water may readily pass in both directions.

The heart is located well forward, close to the branchial pouches, and the blood is driven from the single ventricle through a short aorta into capillaries of the branchial pouches, where aeration takes place and from which the blood vessels unite dorsally to form a dorsal aorta which gives off a vessel supplying the head and various organs of the trunk and tail regions. The excretory organs consist of mesonephric kidneys, which are provided with ducts, the persistent pronephric, or Wolffian ducts, which carry the excretion to the urinogenital sinus.

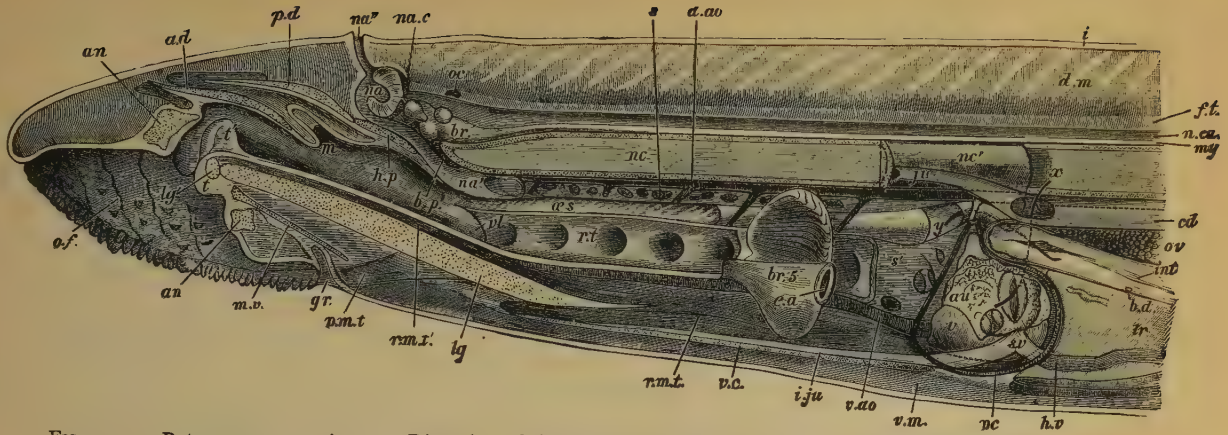


FIG. 210. — **Petromyzon marinus.** Dissection of female. The cartilaginous parts and the sheath of the notochord are dotted. *a.d*, anterior dorsal cartilage; *an*, annular cartilage; *au*, auricle, opened to show auriculo-ventricular aperture below and the sinu-auricular above; *b.d*, aperture of bile duct (abnormal); *b.p'*, portion of basal plate behind basi-cranial fontanelle; *br*, brain; *br. 5*, fifth left gill sac, the upper half cut open; *cd*, left cardinal vein; *d ao*, dorsal aorta; *d.m*, dorsal muscles; *e.a*, external aperture of fifth gill sac; *f.t*, fibrous tissue of neural canal; *gr*, groove below buccal funnel; *h.p*, portion of basal plate anterior to basi-cranial fontanelle; *h.v*, hepatic vein; *i*, integument; *i.ju*, inferior jugular vein; *int*, intestine; *ju*, jugular vein; *lg*, lingual cartilage; *lg'*, small cartilage attached to lingual; *lr*, liver; *m*, buccal cavity; *mv*, median ventral cartilage; *my*, spinal cord; *na*, olfactory sac; *na'*, pituitary pouch; *na''*, nasal aperture; *na.c*, nasal capsule; *nc*, *nc'*, notochord; *n.ca*, spinal canal; *oc*, cranial roof; *æs*, gullet; *o f*, buccal funnel; *ov*, ovary; *pc*, pericardium; *p.d*, posterior dorsal cartilage; *p.m.t*, protractor muscle of tongue; *r.m.t*, retractor of tongue; *r.m.t'*, its tendon; *r.t*, respiratory tube; *s*, *s'*, lymph sinus surrounding gullet; *s.v*, sinus venosus; *t*, *t'*, tongue; *v*, ventricle; *v.ao*, ventral aorta; *v.c*, ventral longitudinal bar of branchial basket; *vl*, velum; *v.m*, ventral muscles; *x*, bristle passed from cardinal vein through sinus venosus into auricle; *y*, bristle passed from gullet into intestine. (From Parker's *Zoötomy*.)

Males and females are separate, and reproduction is simple, the ova and spermatozoa being discharged into the body cavity and passing thence by pores into the urinogenital sinus and thence by the genital aperture to the exterior.

The lampreys cling to stones and other objects under water by means of the sucker-like mouth, and also attach themselves to fishes, rasping away the skin and tissues in order to secure blood, and their attacks are quite often fatal to their involuntary hosts. Even if the blood extracted is not sufficient to kill the fish, the gaping wound which is left is very likely to result in its destruction later.

The larvæ bury themselves in mud with the tail and head just about at the surface of the mud, and by producing currents of water they supply themselves with fresh water for respiration and for the collection of a food supply.

In the lake region of New York these lampreys seem to be persistent, and it is thought possible that they have been cut off from a former course of migration through the streams to the southward, so that their habit has been entirely changed, and that while once fitted for annual migrations to the ocean, they have become adapted to constant fresh-water life.

Lampreys are not used as food, and their main importance from an economic standpoint lies in the attacks which they make upon food fishes. In some localities so large a portion of the fishes which are valuable as food are attacked and injured by these lampreys that it makes a serious inroad upon the fish industry. No very successful method has so far been discovered by which these attacks can be prevented.

The hagfish represents a still more parasitic stage, since it burrows its way into the abdominal cavity of the cod and other oceanic fishes, and may live partly buried within the cavity in a very distinctly parasitic condition. It lives also in mud, and is capable of rapid eel-like swimming. The nostril connects through the nasal cavities with the roof of the alimentary canal.

The skeleton is entirely cartilaginous, and the notochord persists

as the central axis throughout its length ; but there are indications of segmentation. The skull consists of cartilage which forms a distinct brain case, the simplest form of skull which has been encountered thus far. In the auditory organs and the eyes they show relationship to the more primitive vertebrates, although these are seen in some respects to be degenerate, but in the absence of jaws they appear to be decidedly more primitive than any of the forms of vertebrates with distinctly segmented chordal axis. In the arrangement of the respiratory organs there is some indication of common origin with that of fishes, but a very distinct difference of the details in the branchial pouches, which may be considered either as extremely primitive or as a distinct modification from the primitive form which has given rise to a branchial system in fishes.

CHAPTER XVI

Class Pisces

The fishes are a very conspicuous group of aquatic animals, and show in a very high degree the adaptation to aquatic life. Both marine and fresh-water species are abundant, and scarcely any body of water is wanting in some form of the group, and a large number of the species are of great economic importance. The fishery industries based on such forms as cod, salmon, mackerel, herring, whitefish, etc., are of very great extent, and the product forms a very large factor in commerce.

Taking a common fish such as the perch or the sauger (see Figs. 211–213), for example, we may notice the general shape, the head being bluntly pointed and the body compressed, thinning out above and below, and the whole form such as to permit easy movement through the water. The head is rather large and is joined without any neck to the trunk of the body. The eyes are large and round, without lids; the mouth oblique, with the under jaw projecting beyond the upper. At the sides of the head is a large flap or covering, the **operculum**, which incloses the spaces including the gills. The body has two pairs of fins, the anterior ones, or **pectoral**, being homologous with the fore legs or arms of other vertebrates, and the posterior pair, or **ventral** fins, homologous with the hind limbs. There are also fins on the median line, those on the back termed the **dorsal** fins, the tail fin, or **caudal**, which is the principal fin of locomotion, and the **anal** fin situated between the anal opening and the tail. The body is covered with overlapping scales, these beginning close to the head and extending to the base of the tail. The fins are

supported by slender fin rays which are flexible, permitting a wavy motion. Along the side of the body is a series of sensory organs termed the **lateral line**, related in function to the ear, and

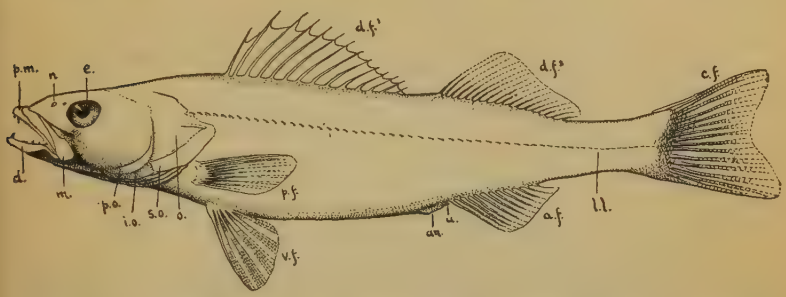


FIG. 211. — Sauger, or sand pike, **Stizostedion canadense**. *e*, eye; *n*, nostril; *df*, dorsal fin, *df. 2*, 2d dorsal fin; *c.f*, caudal fin; *a.f*, anal fin; *v.f*, ventral fin; *p*, pectoral fin; *pm*, premaxilla; *d*, dentary; *m*, maxilla; *o*, opercle; *s.o*, sub opercle; *i.o*, interopercle; *p.o*, preopercle. (From drawing by R. J. Sim.)

opening in a row of scales from the head to the base of the tail. The mouth is provided with sharp teeth pointing backward. The tongue is united with the gill arches. Teeth are borne on a number of structures in the mouth and pharynx, and the gill arches bear appendages called **gill rakers**. The esophagus is narrow

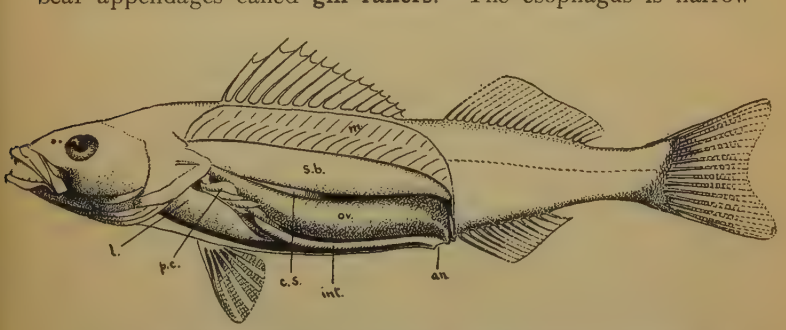


FIG. 212. — Sauger, **Stizostedion canadense**. Dissected from side to show position of internal organs. *l*, liver ; *p.c*, pyloric cæca ; *m*, muscle ; *s.b*, swim bladder ; *c.s*, cæca; *ov*, ovary distended with eggs; *int*, intestine; *an*, anus. (From drawing by R. J. Sim.)

and extends into a rather capacious stomach, this with the intestine being somewhat coiled and terminating in the anal opening situated behind the middle of the body on the median line. The heart is located well forward in the body cavity, and is composed of two chambers, the **auricle** and **ventricle**, the latter connecting by means of a short artery, the **ductus arteriosus**, with the branches that diverge to supply the gills. In the gills the blood vessels break up into minute capillaries and unite again into larger vessels, which combine dorsally and send vessels to the head as

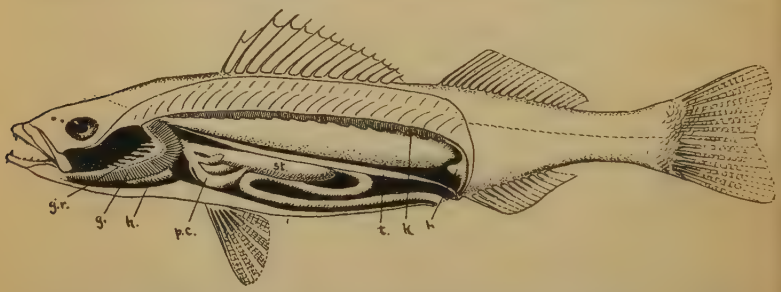


FIG. 213. — Sauger, **Stizostedion canadense**. Dissected from side. *g.r*, gill rakers; *g*, gills; *h*, heart; *pc*, pyloric cæca; *st*, stomach; *t*, testis; *k*, kidney; *b*, bladder. (From drawing by R. J. Sim.)

well as into the dorsal aorta, which extends from the region of the gills backward along the dorsal line to the abdominal cavity, giving off arteries to the stomach, liver, kidneys, and other parts of the body. In these organs again the vessels break up into minute capillaries, and these again combine into veins which form larger ones, and finally unite into two large veins which merge into the **venous sinus**, and this into the auricle. The course of the blood is from the ventricle to the gills, thence by way of the dorsal aorta to the various organs of the body, thence back by the venous system to the auricle. It should be noted here that the aerated blood from the gills does not return to the heart, but is distributed directly to the various tissues. The gills are the organs of respiration, and serve to take up oxygen from the water which flows over them, passing through the mouth and out of the gill slits,

and, also, for the discharge of carbon dioxide. The **air bladder** occurring in fishes is perhaps homologous with the lung, but in the more specialized fishes it cannot be considered as having any functional analogy with the lungs. It is in certain species connected with the alimentary tract by a duct, but in many fishes, the perch among them, this duct has lost all of its tubular connection, and the air bladder is tightly closed and divided into two compartments. The function of the air bladder is probably associated with the regulation of the specific gravity, and may serve to assist the fish in changing its position in the water, compression of the sac of the bladder giving the fish a greater density and permitting it to sink, whereas expansion would have the effect of lightening, and would permit it to rise. The kidneys of the fish are elongated organs extending along the dorsal wall of the abdominal cavity, and discharge their excretion by ducts which open into the urinogenital sinus near the anal opening. The nervous system is located above the axis of the vertebral column, the brain being included within a definite cranial wall, while the spinal cord is partially inclosed by the neural arch from the vertebræ. The parts of the brain are distinct, the olfactory lobes and the optic lobes being conspicuous, the cerebrum comparatively small, with a non-nervous roof, and the cerebellum sometimes remarkably large. These parts with the medulla lie so that each is exposed from above. The sense of smell is probably well developed. Sight is provided for in the large eyes, and hearing by large auditory capsules that have no external ear, but inclose large otoliths which are supposed to intensify the vibrations of the sound waves. The ovaries are large and occupy at the breeding season a large space in the floor of the abdominal cavity. The testes, usually oval or elongate, lie dorsal to the alimentary canal. There are no oviducts, the eggs being discharged into the cœlom, and thence to the exterior by the abdominal pores. The vasa deferentia converge posteriorly and open into the urinogenital sinus close to the anal opening. The eggs are deposited in masses, usually in some kind of nest,

and are fertilized with the milt discharged by the males after the eggs have been deposited. These nests are often guarded by the adult until the young are hatched and able to swim about. The young frequently cluster in schools for a time after hatching.

The fishes present three types of tail fin — the **protocercal**, **heterocercal**, and **homocercal**. In the first the vertebræ extend in a direct line to the end of the tail, and there is a simple lobe. In the second the vertebræ are bent dorsally, and extend into a large upper lobe of the tail fin. In the third the vertebræ terminate abruptly at base of tail, and the upper and lower lobes of tail fin are externally nearly or quite equal.

It is of interest to note that in the development of fishes of the homocercal type the tail vertebræ are first of the protocercal form, later bend upward and resemble the heterocercal, and then shorten and fuse to reach the homocercal condition.

Subclass Elasmobrancha

This group includes the sharks and skates, and is characterized by the rough body surface, the skin not being provided with overlapping scales but with minute imbedded spines or denticles which give a rasp-like surface to the skin. In the sharks the body is slightly flattened in the anterior part, but in the skates and rays there is a very marked flattening of the body, the pectoral fins being carried out to extreme angles on the side of the body. The mouth is on the ventral side, and is a broad transverse slit armed with sharp teeth, the points of which are usually directed backward, but in skates and rays they are broad and flattened, and form a sort of pavement in the mouth. The gill slits open independently at the side of the head in sharks but on the under side of the much-flattened head of the skates and rays, and there is a dorsal opening, the spiracle, through which water may be ejected. The eyes are dorsal, and no external ears are present. The skeleton is entirely cartilaginous, but in the vertebral column becomes hardened by deposits of lime. The vertebræ are strongly biconcave, and the concavities of the two

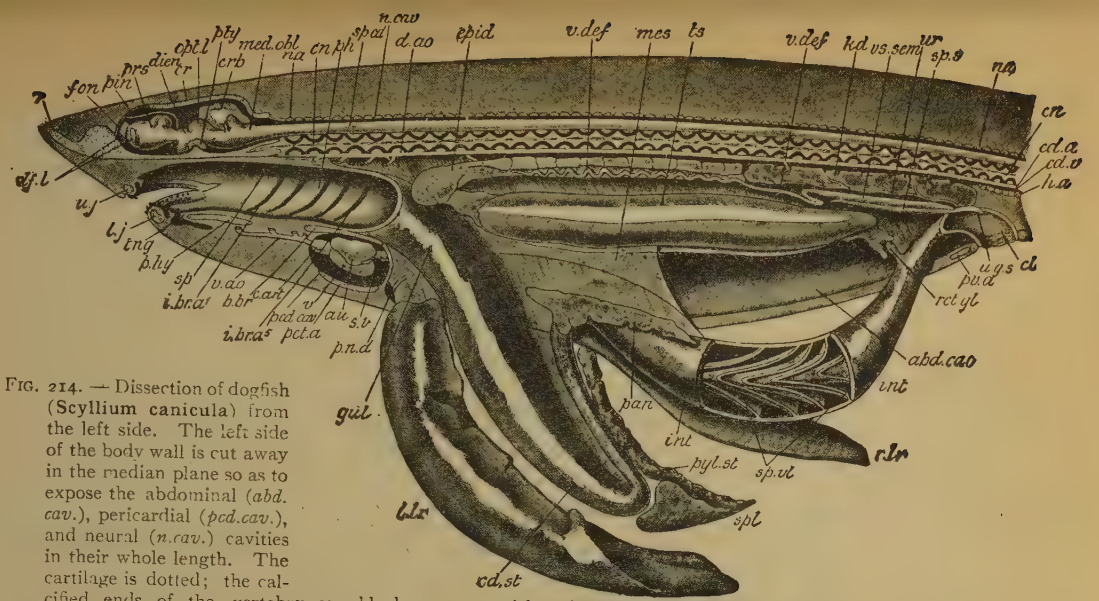


FIG. 214. — Dissection of dogfish (**Scyllium canicula**) from the left side. The left side of the body wall is cut away in the median plane so as to expose the abdominal (*abd. cav.*), pericardial (*pcd.cav.*), and neural (*n.cav.*) cavities in their whole length. The cartilage is dotted; the calcified ends of the vertebræ are black. *au*, auricle; *b.br*, basi-branchial cartilage; *b.hy*, basi hyal; *c.art*, conus arteriosus; *cd.si*, cardiac portion of stomach; *cd.v*, caudal vein; *cl*, cloaca; *cn*, centra; *cr*, cranium; *crb*, cerebellum; *d.ao*, dorsal aorta; *dien*, third ventricle; *epid*, epididymis; *fon*, fontanelle in roof of skull; *h.a*, hæmal arches; *i.br.a*^{1}, *i.br.a*^{6}, internal branchial apertures; *int*, intestine; *kd*, kidney; *l.j*, lower jaw; *l.lr*, left lobe of liver; *med.obl*, medulla oblongata; *n.a*, neural arches; *olf.l*, olfactory lobe; *opt.l*, optic lobe; *pan*, pancreas; *pct.a*, pectoral arch; *ph*, pharynx; *pin*, pineal body; *pr.s*, prosencephalon; *pty*, pituitary body; *pv.a*, pelvic arch; *r*, rostrum; *rct.gl*, rectal gland; *r.lr*, right lobe of liver; *sp*, spiracle; *sp.cd*, spinal cord; *spl*, spleen; *sp.s*, sperm sac; *vs.sem*, vesicula seminalis; *sp.vl*, spiral valve; *s.v*, sinus venosus; *tng*, tongue; *ts*, testis; *ug.s*, urogenital sinus; *u.j*, upper jaw; *ur*, ureter; *v*, ventricle; *v.ao*, ventral aorta; *v.def*, vas deferens. (Parker and Haswell.)

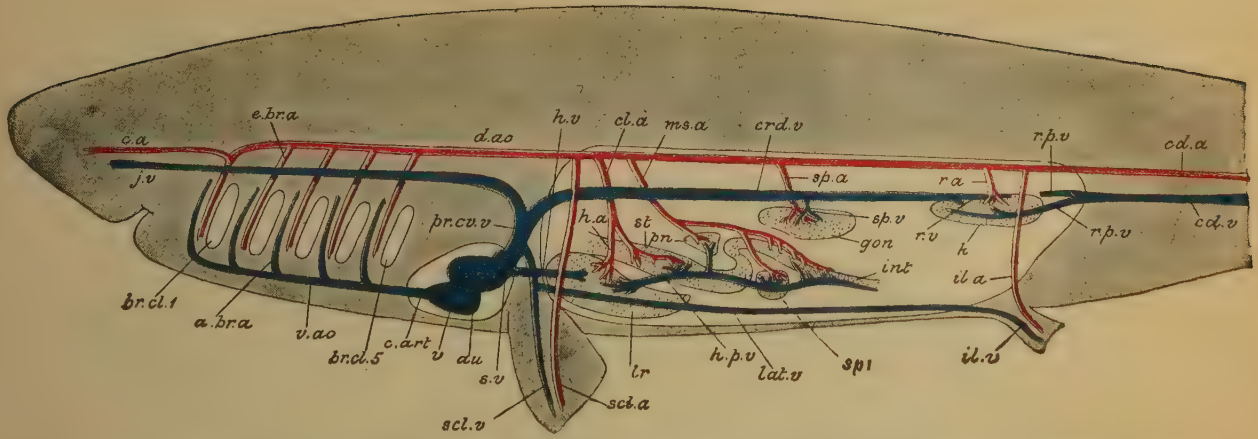


FIG. 215. — Diagram of the vascular system of a fish. Vessels containing aerated blood red, those containing non-aerated blood blue. *a.br.a*, afferent branchial artery; *au*, auricle; *br.cl. 1–5*, branchial clefts; *c.a*, carotid artery; *c.art*, conus arteriosus; *cd.a*, caudal artery; *cd.v*, caudal vein; *cl.a*, cœliac artery; *crd.v*, cardinal vein; *d.ao*, dorsal aorta; *e.br.a*, efferent branchial artery; *gon*, gonad; *h.a*, hepatic artery; *h.p.v*, hepatic portal vein; *hv.*, hepatic vein; *il.a*, iliac artery; *il.v*, iliac vein; *int*, intestine; *j.v*, jugular vein; *k*, kidney; *lr*, liver; *lat.v*, lateral vein; *ms.a*, mesenteric artery; *pn*, pancreas; *pr.cv.v*, precaval vein; *r.a*, renal artery; *r.p.v*, renal portal vein; *r.v*, renal vein; *scl.a*, subclavian artery; *scl.v*, subclavian vein; *sp.a*, spermatic artery; *spl*, spleen; *sp.v*, spermatic vein; *st*, stomach; *s.v*, sinus venosus; *v*, ventricle; *v.ao*, ventral aorta. (From Parker and Haswell.)

sides are connected at the center, and the space formed between the adjacent vertebræ is filled by notochordal tissue which is therefore practically continuous in a series of lenticular bodies. A fairly complete brain box is formed by cartilage. The mouth is large and capacious and opens laterally into the gill slits, then narrows sharply for the beginning of the esophagus, and then widens into a stomach and intestine, which is provided with a special fold, the function of which is to give additional absorbing surface as well as to retard the progress of the food material in its passage along the canal. The heart is located well forward, close to the base of the gills.

Most of the species are oviparous and produce large eggs inclosed in tough leathery capsules which are often provided with long tendril-like structures which serve to fasten the egg to seaweed, stones, stems of coral, or other support. In a few species the young are brought forth alive. The group is separated into two main orders, the Selachii and the Holocephali, the former group, including

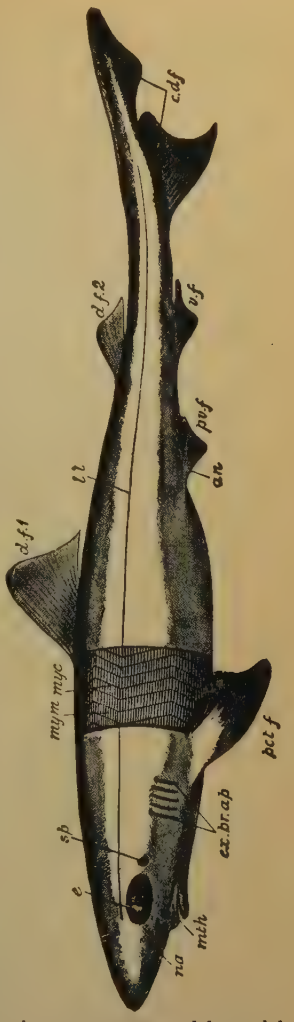


FIG. 216. — Side view of dogfish (**Mustelus antarcticus**), with a strip of skin in the middle of the body removed to show the muscles. *an*, anus; *c.d.f*, caudal fin; *d.f. 1*, *d.f. 2*, dorsal fins; *e*, eye; *ext.br.ap*, external branchial apertures; *l.l*, lateral line; *mth*, mouth; *myc*, myocommas; *mym*, myomeres; *n.a*, nasal aperture; *pct.f*, pectoral fin; *pv.f*, pelvic fin; *sp*, spiracle; *v.f*, ventral fin. (From Parker's *Biology*.)

the common sharks and rays, comprising most of the existing forms.

While most of the species of this group are looked upon as of slight economic importance, they are of interest because of their predaceous habits. There are some of the species which from their attacks on valuable food animals and their abundance occupy quite an important position among marine animals. The common dogfish, which is a very abundant species along the Atlantic coast, has been shown to be a very important factor in the depletion of the lobster fisheries, consuming immense numbers of this valuable crustacean. On this account considerable study has been given to methods by which they may be controlled, and the most important suggestions are probably those which involve its greater utilization in commerce. It furnishes valuable products in the form of skins, oil, and materials for glue and fertilizers, and the Bureau of Fisheries strongly urges an effort to introduce the use of its flesh as food. It is claimed that while used to a very small extent in this country in this manner, it is used quite largely in other countries, and that the flesh is not only nutritious, but is also palatable, and that if the prevailing prejudice against it were overcome, it would prove a most valuable addition to the food supply of commerce.

Some of the larger sharks are very dangerous in bays or shallow water from their attacks upon bathers. The larger species reach a length of from fifteen to seventeen feet, and can easily kill a man. Sharks are essentially free-swimming forms, living upon refuse thrown from ships and on aquatic animals which they capture in open water. The skates and rays, which are adapted by their much-flattened form for living at the bottom, remain there constantly, sometimes partially buried in mud or sand, but occasionally swimming about for a short distance, their locomotion being accomplished by flapping movements of the large pectoral fins. Their food consists of mollusks and other animals living at the bottom. The electric ray has a remarkable ability to discharge a very severe electric shock.

The second order, Holocephali, includes some very remarkable species, the chimeras, which are, however, of very little economic importance.

Subclass Teleostomi

In this group is included a great number of our common fishes, and they are for the most part provided with bony skeletons, or at least with some bony parts in the skeleton. The gills are covered by a distinct bony plate, the operculum, so that there is but one external gill opening. The tail is either heterocercal or distinctly homocercal.

The order **Ganoidei** appear to be much more primitive than the other members of the group, and they are but few in number among the existing fishes, although the group was abundant in earlier geological times. The vertebral column is cartilaginous, and the brain is inclosed in a bony cranium in which we find an arrangement of bones which is essentially similar to that of the vertebrate groups which follow. These bones are developed in the dermis and correspond with what are known as the membrane bones in the skeletons of the higher vertebrates. The body is covered with bony plates which in the gar pikes fit closely together so as to make a complete bony armor. The tail is heterocercal.

Our common sturgeon is one of the larger members of this group and occurs in fresh waters throughout the larger part of North America and Europe. The snout is elongated, overlapping the mouth so that the position of the mouth resembles that of the sharks. The body has a series of large bony plates along the back and on the side and beneath, and the remainder of the body is protected by minute bony plates imbedded in the skin. The upper part of the tail is very much longer than the lower and includes a distinct series of vertebræ. The sturgeon is a valuable food fish and is much sought for in all the localities where it occurs.

The spade catfish, which occurs in the Mississippi River and its tributaries, has a very large, flattened prolongation of the snout,

and the skin is soft and much resembles that of the catfishes; but the tail is distinctly heterocercal, the upper part being nearly as long in proportion to the other parts as in the sturgeon. The gar pikes are interesting forms occurring throughout the greater part of the United States, there being three distinct species. The body is covered with closely fitting bony plates and the tail is slightly heterocercal. In the long-nosed gar the head is much prolonged and the jaws are five or six inches long and provided with many teeth. The short-nosed gar, which has jaws about one half as long and reaches a length of about one and a half to two feet, occurs commonly throughout the northern United States. The alligator gar is provided with a broader head, comparatively short jaws, and reaches a length of from four to five feet, but is not known north of the Gulf States.

The bowfin or dogfish common in the fresh waters of northern United States is a more completely bony skeletoned fish and is apparently an intermediate form between the species already mentioned and the true bony fishes, the Teleostei. It is of no particular commercial importance.

Order Teleostei. — The teleosts, or bony fishes, are at the present time the most numerous and important members

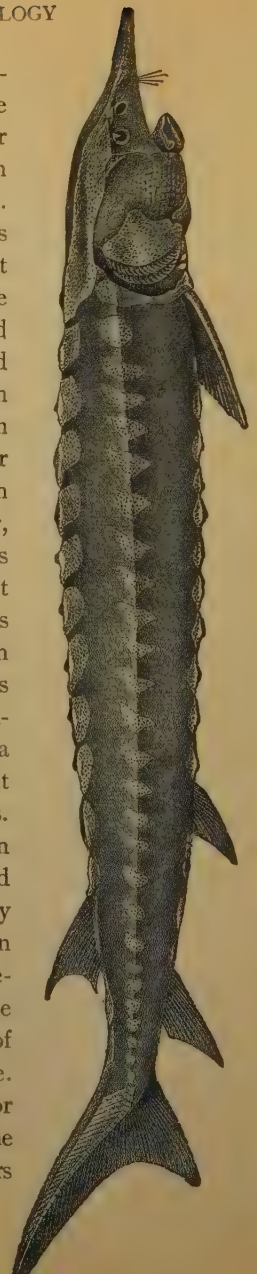


FIG. 217. — **Acipenser sturio**, the sturgeon. (After Day, from Shipley and McBride.)

of the group. They abound in all bodies of water, either oceanic or fresh water, down to the smallest ponds and pools, and many of the species are of very great economic importance, being used very extensively as food. The skeleton is composed of osseous tissue, and the vertebræ as well as the bones of the skull and appendages are ossified. The vertebræ are strongly biconcave. The body in most of the groups is covered by overlapping scales, but in some forms, like the catfishes and eels, the scales are entirely wanting, while in certain fossil forms the skin is ossified and the whole body protected by bony plates. Usually there is a swim bladder which, in some forms, is connected with the alimentary canal, and which in many of our common fishes is permanently inflated and sometimes divided into two distinct compartments. The tail is homocercal, the vertebral column terminating abruptly at the base of the fin rays; but frequently a sharp, fused section directed dorsally indicates the derivation of this structure from the heterocercal form. In most species, reproduction is oviparous and eggs are produced in great numbers, those of the cod being estimated at one million for each spawning. Some of the species provide distinct nests and protect the eggs during early stages of development, but in the majority of cases the eggs are discharged freely into the water and depend upon chance of numbers for escape from the other aquatic animals which feed upon them. In many cases the eggs are lighter than the water and float at the surface until the young fishes are ready to hatch. Adaptations to almost all possible conditions of aquatic life are represented in the group and a few have become fitted for living out of the water for a certain length of time. The flying fishes simply dart into the air and travel for short distances in an abortive sort of flight. The climbing perch is able to crawl out of the water and ascend trees, there being a secondary respiratory organ provided for the utilization of air in respiration in the upper part of the gill cavity.

A short survey of some of the principal groups with reference to those species which have the greatest economic importance is all that we can attempt.

The catfishes, *Siluridæ*, are an extensive group of fresh-water species distinguished at once by the smooth skin without scales and by the rather broad, flattened heads and the numerous barbels, which are slender, flexible appendages around the mouth. Most of the species, such as the horned pout, bull heads, or common catfish, are small and of excellent quality and commonly used as food, while the channel cat reaches a weight of about twenty-five pounds.

The suckers, *Catostomidæ* have a mouth provided with a flexible extension which they use in feeding upon animals caught at the bottom of the water and by burrowing into the mud. They are not of high quality, but because of the ease of capture are used to some extent as food fishes.

The carp family, *Cyprinidæ*, aside from the common carp, includes the goldfishes and tench which are very commonly kept in semi-domestication. A large number of the species come under the common name of minnows and have their main utility as bait for other fishes or as food supply for the larger and more important species. The European carp which was introduced into the United States some time ago is now established very generally in the rivers and lakes throughout the country and at present constitutes a very important article of commerce. While not generally prized by Americans as a food fish, it is a favorite among a large class of the European immigrants and is sold in immense numbers in the markets of some of the larger cities. Goldfish and tench are interesting ornaments in aquaria and fountains.

The salmon family, *Salmonidæ*, includes a large number of very important food fishes, the most important commercially. Perhaps the species entering into the commerce of the world more widely than any other fish is the Pacific coast salmon, which is found the world over in the canned condition. It is one of the choicest food fishes and especially if taken in the fresh condition is of superior flavor. These fishes ascend the rivers of the Pacific coast in large numbers and are caught in traps and in various

other ways in such quantities as to supply the markets of the world. The fishes ascend the rivers to spawn, and in these migrations sometimes reach one thousand or more miles from the shore. It is said that they ascend the streams but once and that after the eggs are deposited the fish dies. Inasmuch as the fishes are of very different size and presumably of quite different ages

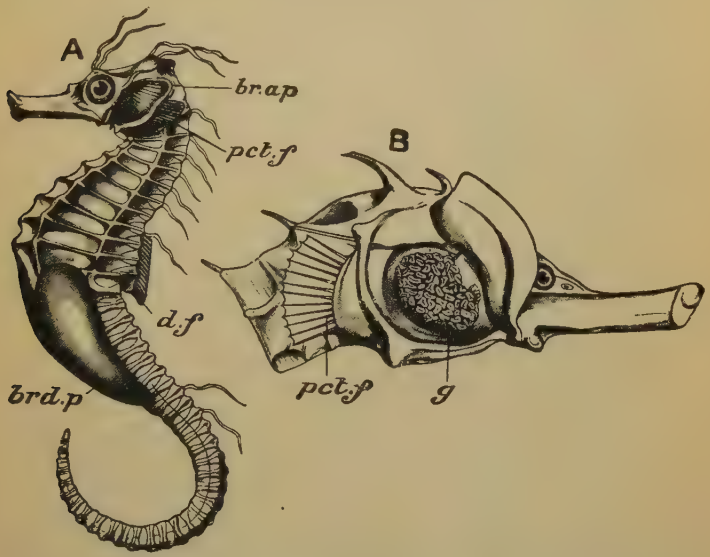


FIG. 218. — **Hippocampus** (sea horse). In B, the operculum is removed to show the gills. *br.ap*, branchial aperture; *brd.p*, brood pouch; *d.f*, dorsal fin; *g*, gills; *pct.f*, pectoral fin. (From Claus and Günther.)

in the swarms which enter the rivers it appears that the instinct to enter the rivers for spawning must be deferred in some individuals until a much later age than in others. The lake salmon, grayling, European salmon, and other species are valuable for food supply.

The brook trout or spotted trout of the eastern United States, which is accounted as the finest of game fish, is another species, but it is not taken in such numbers as to make it an important

commercial species. Trout fishing, however, is undoubtedly one of the finest and most healthy sports which can be indulged in.

The codfish, representing another family, the *Gadidæ*, is a marine fish occurring in the northern hemisphere and is one which comes into commerce perhaps as largely as any species except the salmon. It is marketed very largely in the fresh condition throughout the eastern seaports and in the salted form is a staple article of commerce. Cod fishing is an industry which engages the attention of thousands of individuals and involves a capital of many millions invested in boats and apparatus. The haddock, a nearly related species, is similar in habits and is also quite desirable for food. The pike and pickerel, *Esocidæ*, have a rather elongate body and the species acquire a considerable size, the largest, the muskellunge, reaching a length of over four to eight feet. This occurs in the larger rivers and lakes of the northern United States and is a valuable game fish. The smaller species of pike and pickerel are much more generally caught and constitute a considerable source of profit to fishermen, as they are much prized as a table delicacy.

In the family including the bass we have also a considerable number of important commercial species, — the white bass, black bass, and rock bass being of fine quality. Of these the black bass is perhaps the most sought for as a game fish on account of the difficulty of catching it. Here, too, we have the little sunfishes and breams, or pumpkin seeds, which are the delight of the

FIG. 219. — **Polypterus birchir.** A, entire animal; B, ventral view of throat. *an*, anus; *br.m*, branchiostegal membrane; *c.f*, caudal fin; *d.f*, dorsal finlets; *jug. pl*, jugular plates; *na*, nostril; *pct.f*, pectoral fin; *pv.f*, pelvic fin; *v.f*, ventral fin. (After Cuvier.)

small boy. The family of perch includes also many species which are valuable food fishes. The common yellow perch which abounds in most streams and especially in bays and coves of the lakes is, on account of its abundance and the ease of its capture, one of the most commonly used. It is of excellent flavor but must be eaten fresh from the water to be at its best.

The whitefish of the lake region is one of the most important commercial species, immense quantities being sold in the markets of the lake ports and shipped to a considerable distance inland.

The flounders and halibut form an extensive and interesting group of a high commercial value and are of particular interest on account of the peculiar adaptation in shape of body to their mode of living. These fishes lie upon one side of the body and are sometimes buried partly in the mud or sand. They lie persistently on the side of the body, which as a result of its protection from light loses the ordinary color and becomes slightly softer, and the scales are weaker than for the side which is uppermost. There is also a remarkable change in the position of the eye, which would commonly be on the under side. This begins at an early stage in the growth of the fish to migrate across to the opposite

FIG. 220. — **Ceratodus Forsteri.** Reduced. (From Dean, after Günther.)

side of the head so that both eyes come to occupy the side of the head which is uppermost in the ordinary position of the fish. The mouth remains in its normal position and appears to be practically unchanged. The gill slits are in the usual position and most of the water is discharged through the slit which is uppermost in position. The pectoral and ventral fins are small and weak, and the dorsal and anal fins become very much elongated and form a border for nearly the entire length of the body. The caudal fin is usually rather small. A remarkable feature of these fishes is that when they hatch from the egg they are of the ordinary form of fish and for a time swim about in the vertical position, but later begin to rest at the bottom and their bodies change into the form which is adapted to this position. During this period migration of the eye takes place, this necessarily being before the bones of the head have become ossified. This development indicates very clearly that the flounders have descended from fishes which had an ordinary position and free-swimming habit and as a result of the specialized life there has been a

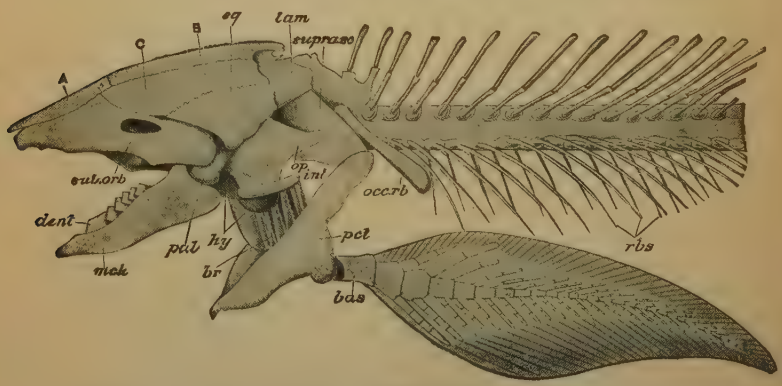


FIG. 221. — **Ceratodus Forsteri**. Lateral view of the anterior portion of the skeleton. A, anterior median membrane bone of the roof of the skull; B, posterior median membrane bone. *bas*, basal cartilage of the pectoral fin; *br*, branchial arches; *int*, interoperculum; *lam*, plate overhanging branchial region; *mck*, Meckel's cartilage; *occ.rb*, occipital rib; *op*, operculum; *pal*, palato-quadrate; *pct*, pectoral arch; *rbs*, ribs; *sub.orb*, suborbital bones; *sq*, squamosal; *supra.sc*, suprascapula. (From Parker and Haswell.)

corresponding modification of structure which fits them for this habit and which makes it impossible for them now to survive in any other manner.

Subclass Dipnoi

The lungfishes are an interesting division because of their showing so many points of advancement toward the land-inhabiting air-breathing conditions. *Polypterus* occurs in South Africa, *Ceratodus* in Australia, and *Lepidosiren* in South America, showing wide distribution and suggesting remote antiquity for a common ancestral form.

CHAPTER XVII

Class Amphibia

This group, including frogs, toads, salamanders, and newts, is of particular interest in connection with the transition from aquatic to terrestrial life in the group of vertebrates. Most of the species while aquatic in early stages reach a condition where they leave the water and depend upon lung respiration and show adaptations of the circulatory system to this change. Of the various common species that are available for study, the marsh frog is perhaps the most convenient and has been most commonly used as a type of the group. In many respects it serves also as a good type of structure for the vertebrates in general.

The frog is from three to four inches in length and is provided with hind legs of large size fitting it for jumping. The front legs are much shorter and weaker than the hind ones. The head merges with little indication of a neck into the thorax and has conspicuous eyes situated well up on the head so that they project above the water when most of the head is submerged. The nostrils lie close to the anterior margin and connect by passages with the roof of the mouth. The mouth is broad and very capacious, the floor consisting of delicate muscles and flexible skin, and comes into use in the production of the note so commonly heard in the early spring. The fore feet are provided with four toes, which are short and weak, and the hind feet with much larger and stronger toes united by a web which serves in swimming. The trunk is short and there is no tail. The surface is blotched and spotted somewhat regularly and the under surface is a greenish white.

The muscular system is well developed, and the principal muscles can be most readily seen by reference to figures in which location and attachment are shown.

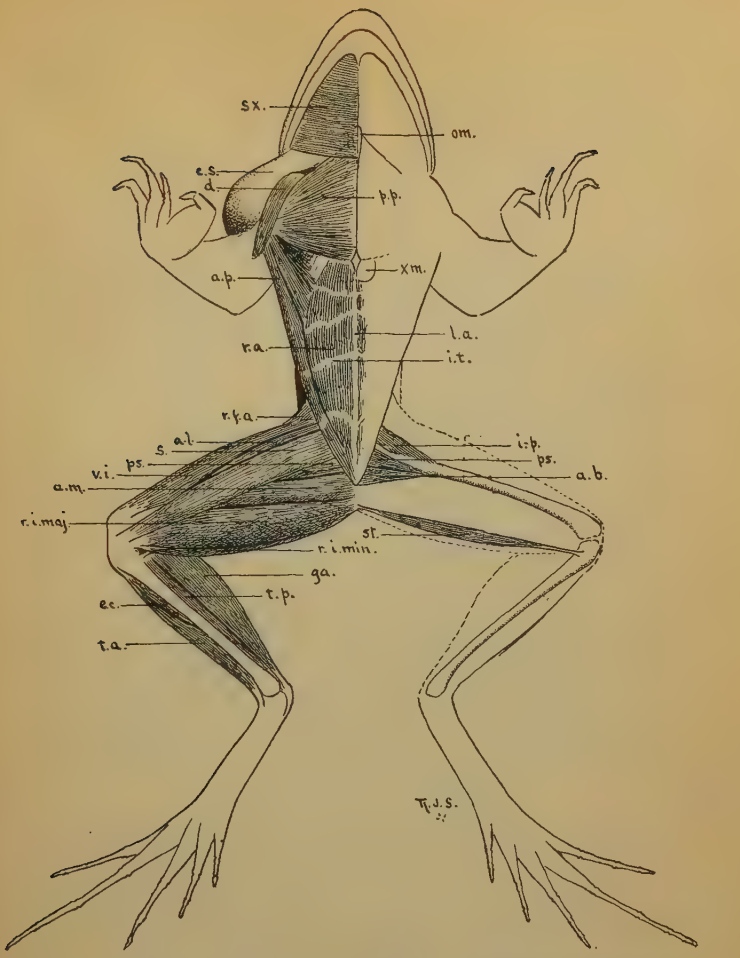


FIG. 222. — Muscles of frog, **Rana virescens.** *s.r*, superior rectus; *pt*, pterygoideus; *tr*, temporalis; *d.m*, depressor maxillæ; *is*, infraspinatus; *cu*, circularis; *ld*, latissimus dorsi; *tr*, triceps; *e.o*, external oblique; *c.i*, coccygeo-iliacus; *gl*, gluteus; *v.e*, vastus externus; *bi*, biceps; *s.m*, semimembranosus; *r.i.min*, rectus internus minor; *t.a*, tibialis anticus; *pe*, peroneus; *ga*, gastrocnemius; *e.d*, extensor dorsi; *i.p*, ilio psoas; *q.f*, quadratus femoris; *py*, pyriformis; *t.p*, tibialis posticus; *r.s*, rectus superior; *p.p*, pectoralis proper; *d*, deltoid; *a.p*, abdominal pectoralis; *a.l*, adductor longus; *v.i*, vastus internus; *s*, sartorius; *r.i.maj*, rectus internus major; *a.m*, adductor magnus; *st*, semitendinosus; *a.b*, adductor brevis; *ps*, pectineus; *r.a*, rectus abdominis; *sx*, submaxillaris; *om*, omosternum; *xm*, xiphisternum; *l.a*, linea alba; *i.t*, inscriptis tendinea. (From drawings by Mr. R. J. Sim.)

Frogs in the adult form feed upon insects and may be considered as serviceable in that they assist in keeping in check certain kinds

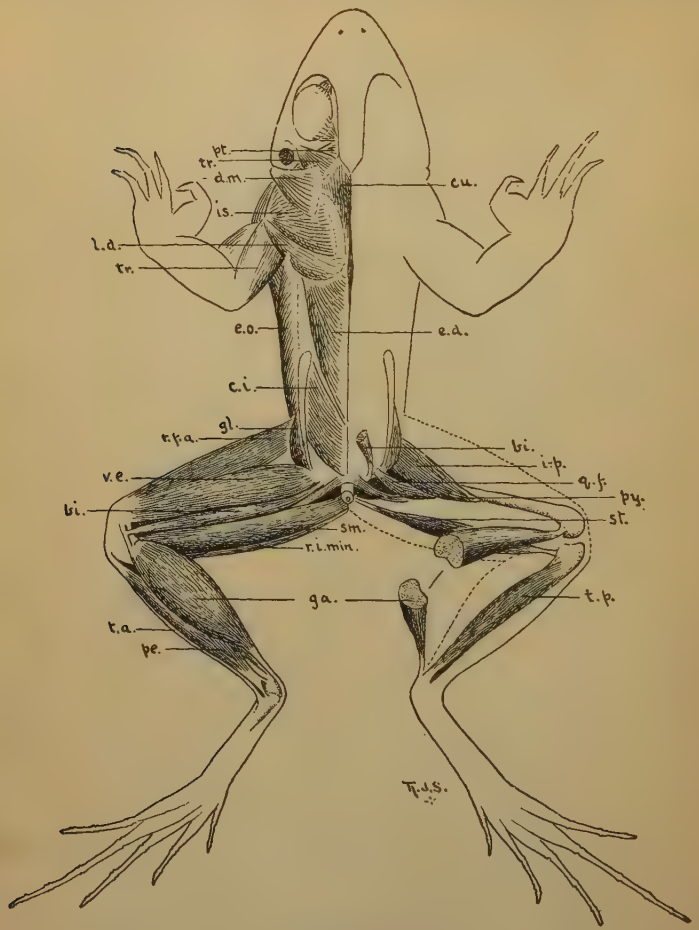


FIG. 223. — Muscles of frog. Letters as in Fig. 222. (From drawing by Mr. R. J. Sim.)

of injurious pests. The mouth includes a short tongue attached by its anterior end. This is capable of being thrown outward

and is used in the capture of prey. The esophagus is rather slender and extends into a quite capacious stomach. The intestine is rather short and slightly coiled and terminates in an anal opening situated slightly to the dorsal side. The heart has three cham-

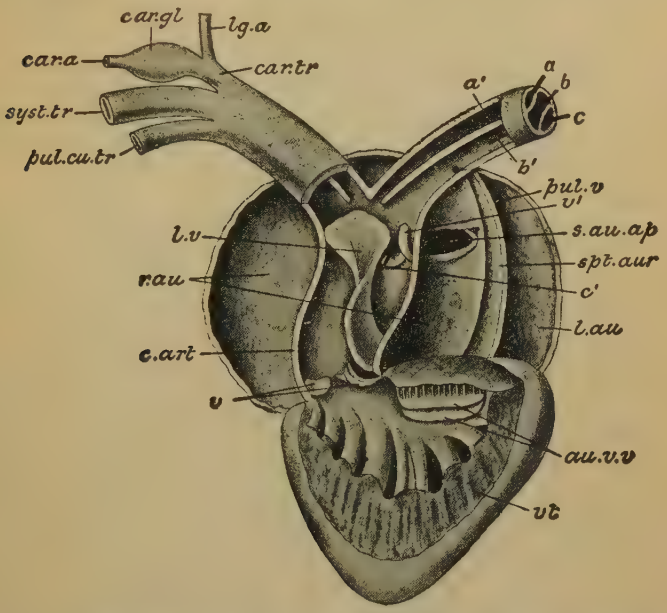


FIG. 224. — **Rana temporaria.** The heart from the ventral aspect with the cavities laid open. *a'*, *a*, bristle in left carotid trunk; *au.v.v*, auriculo-ventricular valves; *b*, *b'*, bristle in left systemic trunk; *c*, c^1, bristle in left pulmocutaneous trunk; *car.a*, carotid artery; *car.gl*, carotid plexus; *c.art*, conus arteriosus; *car.tr*, carotid trunk; *l.au*, left auricle; *lg.a*, lingual artery; *l.v*, longitudinal valve; *pul.cu.tr*, pulmo-cutaneous trunk; *pul.v*, aperture of pulmonary veins; *r.au*, right auricle; *s.au.ap*, sinu-auricular aperture; *spt.aur*, septum auricularum; *v*, v^1, valves; *vt*, ventricle. (After Parker and Haswell.)

bers, two auricles and one ventricle, and the former receive blood respectively from the systemic circulation and the lungs, and the latter forces the blood by way of the carotid and systemic trunks to the system generally, and by the pulmocutaneous arteries to the lungs and skin. While containing a single cavity,

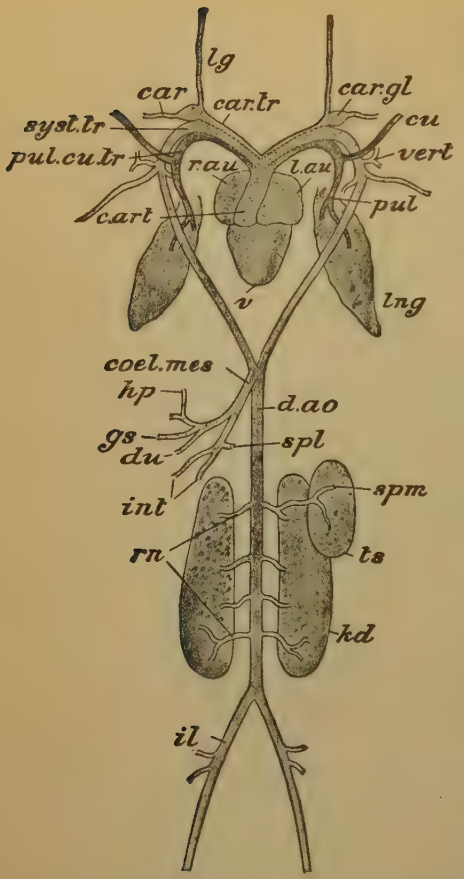


FIG. 225. — **Rana temporaria.** The arterial system, with the heart, lungs, kidneys, and left testis, from the ventral aspect. *car*, carotid artery; *car. gl*, carotid gland; *c.art*, conus arteriosus; *car.tr*, carotid trunk; *cœl.mes*, cœliaco-mesenteric artery; *cu*, cutaneous artery; *d.ao*, dorsal aorta; *du*, duodenal artery; *gs*, gastric artery; *hp*, hepatic artery; *il*, iliac artery; *int*, intestinal arteries; *kd*, kidney; *l.au*, left auricle; *lg*, lingual artery; *pul*, pulmonary artery; *pul.cu.tr*, pulmo-cutaneous trunk; *r.au.*, right auricle; *rn*, renal arteries; *spl*, splenic artery; *sys.tr*, systemic trunk; *spm*, spermatic artery; *ts*, testis; *v*, ventricle. (After Parker and Haswell.)

the ventricle is somewhat spongy, and there is some separation of venous and arterial blood owing to an arrangement of valves in the conus arteriosus. The conus divides into a right and left branch, the systemic trunks of which are curved dorsally and extend back, uniting in the median part of the pleuroperitoneal cavity, and from the joined dorsal aorta are given off the arteries of the stomach, intestine, and kidneys, and posteriorly it branches into the iliac arteries which supply the arterial system of the hind legs. The venous system, combined from the capillaries, parallels the arteries in most of its course,

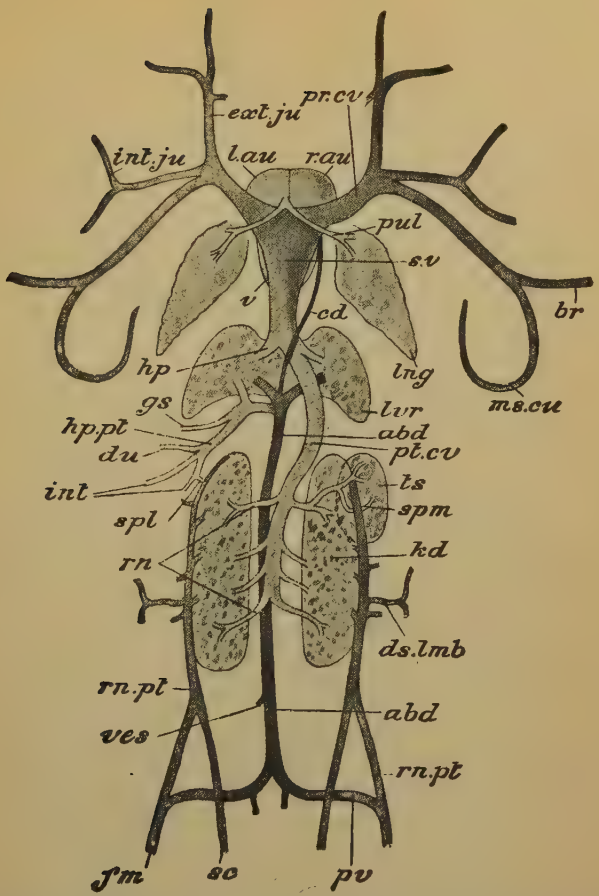


FIG. 226. — **Rana temporaria**. The venous system with the heart, lungs, liver, kidneys, and right testis, from the dorsal aspect. *abd*, abdominal vein; *br*, brachial vein; *cd*, cardiac vein; *ds.lmb*, dorso-lumbar vein; *du*, duodenal vein; *ext.ju*, external jugular vein; *fm*, femoral vein; *gs*, gastric vein; *hp*, hepatic vein; *hp.pt*, hepatic portal vein; *int*, intestinal veins; *int.ju*, internal jugular vein; *kd*, kidney; *l.au*, left auricle; *lng*, lung; *lvr*, liver; *ms.cu*, musculo-cutaneous vein; *pr.cv*, precaval vein; *pt.cv*, postcaval vein; *pul*, pulmonary vein; *pv*, pelvic vein; *r.au*, right auricle; *rn*, renal veins; *rn.pt*, renal portal vein; *sc*, sciatic vein; *spl*, splenic vein; *spm*, spermatic vein; *s.v*, sinus venosus; *ts*, testis; *ves*, vesical veins. (After Parker and Haswell.)

particularly in the limbs, and unites into the **sinus venosus**, the contents being discharged into the right auricle. The pulmonary veins, formed from the union of capillaries in the lungs, discharge their blood supply into the left auricle.

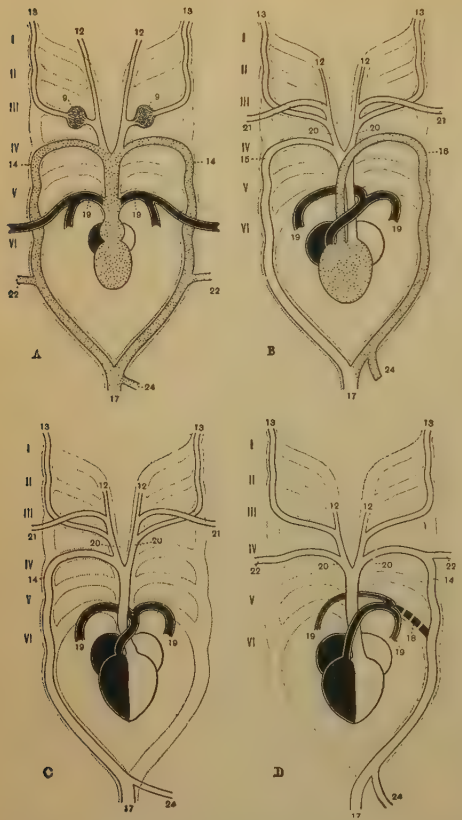


FIG. 229. — Diagram of arterial arches of A, frog; B, turtle; C, bird, and D, mammal, viewed from the ventral aspect. I, II, III, IV, V, VI, first to sixth arterial arches; *9*, carotid gland; *12*, tracheal (ventral carotid), lingual of frog; *13*, common carotid (dorsal carotid); *14*, systemic arch; *17*, dorsal aorta; *18*, ductus arteriosus; *19*, pulmonary; *20*, innominate; *21*, subclavian (ventral type); *22*, subclavian, or equivalent intercostal; *24*, cœliaco-mesenteric in frog. (Adapted from Shipley and McBride.)

The circulation in vertebrates in general is of particular interest and significance in that it shows a fairly well connected, progressive line of evolution from the simpler plan present in the lowest group up to the complex conditions present in birds and mammals, and as the amphibian marks the transition from water to land, the vascular system of the frog shows some most important steps in this evolution. Taking as a basis the general plan found in the lamprey, we have a ventral tube, part of

which is modified into the pulsating organ, the heart, from which vessels carry the blood current forward to the gills. From these it is collected into a dorsal vessel and distributed to the various organs, part being carried forward to the head and part backward to other parts of the body. After passing the capillaries it is collected into the ventral tube, from which on entering the heart it receives the impulse for another circuit. This type prevails throughout the fishes, except that it is slightly modified for the lungfishes, and is also the fundamental type in the larval stages of amphibians. An important feature in this circulation is that the blood receives the impulse from the heart but once during the complete circuit, there being no return of the blood to the heart immediately after aeration. With the assumption of air breathing, however, the gill circulation is eliminated and the lung circulation acquired, and with this accession there is a distinct change in the circuit, the blood being taken from the lungs back to the heart, where in adult amphibians and in reptiles it enters by a separate chamber, there being two auricles, but mingles in the single ventricle from which blood is sent both to the systemic circulation and to the lungs. The further perfection of this system commenced in reptiles and completed in birds and mammals is based on the division of the ventricle, so that the two circulations are kept entirely separate. The derivation of this from the amphibian and reptilian form is clearly apparent in the relations of the blood vessels, but there is a striking difference in the two groups in that the persisting gill arch or aortic arch is, in birds, the right arch, while in mammals it is the left. This one feature would suggest that the birds and mammals have had their derivation from the more generalized groups, and that neither one can be considered as derived from the other. There is in the whole development and perfecting of this system, therefore, a most complete series of modifications and a very significant line of evidence regarding the affinities of these various groups.

The lungs have distinctly chambered walls and their cavities arise from the two main bronchi which arise from the trachea.

The trachea opens in a narrow slit, the glottis, below the tongue in the floor of the mouth. The kidneys are much more compact than in fishes, having distinctly oval form and being located posteriorly in the dorsal portion of the abdominal cavity, and their ducts, the ureters, open separately into the bilobed allantoic bladder, which opens by a short urethra into the rectum close to the anal opening.

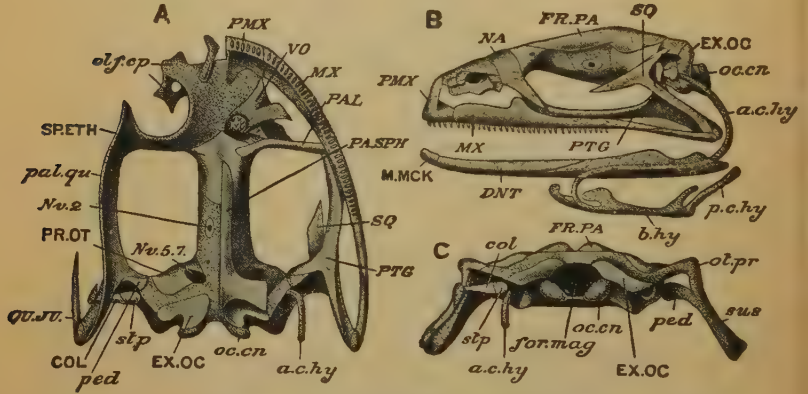


FIG. 228. — **Rana temporaria.** The skull. A, from beneath, with the membrane bones removed on the right side (left of figure); B, from the left side, with mandible and hyoid; C, from behind. *a.c.hy*, anterior cornu of hyoid; *b.hy*, body of hyoid; **COL**, columella; *DNT*, dentary; **EX.OC**, exoccipital; *for.mag*, foramen magnum; *FR.PA*, fronto-parietal; **M.MCK**, mento-meckelian; *MX*, maxilla; *NA*, nasal; *Nv. 2*, optic foramen; *Nv. 5*, *7*, foramen for fifth and seventh nerves; *oc.cn*, occipital condyle; *olf.cp*, olfactory capsule; *ot.pr*, otic process; *PAL*, palatine; *pal.qu*, palato-quadrate; *PA.SPH*, parasphenoid; *p.c.hy*, posterior cornu of hyoid; *ped*, pedicle; *PMX*, premaxilla; **PR.OT**, prootic; *PTG*, pterygoid; *QU. JU*, quadrato-jugal; **SP.ETH**, sphenethmoid; *SQ*, squamosal; *stp*, stapes; *VO*, vomer. (After Howes, slightly altered.)

The nervous system, while on the same plan as that of the fishes, shows a greater development of the brain. The optic lobes are large, the cerebellum small, and the spinal cord is short and breaks up posteriorly into a large number of nerves passing to the posterior legs. The senses are well developed, sight being represented by two prominent eyes which are provided with lids. The ears are

quite conspicuous, having a large tympanic membrane on either side of the head, behind the eye, this connecting by an internal rod of bone and cartilage, the outer end of which is attached to the tympanic membrane and its inner end to the stapes, which rests upon the inner ear. The special organs for smell and taste and touch are not developed in an unusual manner. The internal nares open into the front part of the mouth.

The skeleton is considerably modified and is not constructed on so general a plan as is found in the salamander. The skull includes a small cranial cavity inclosing the brain, and the maxillary bones forming the jaws are broadly arched and separated posteriorly by the pterygoid and squamosal bones. The vertebral column is short, the caudal vertebræ being fused into a long, slender bone, the **urostyle**. The ribs are wanting, the vertebræ possessing short transverse processes, and the pectoral girdle is composed of three parts, — the coracoid, clavicle, and scapula, the latter possessing a dorsal projection, the suprascapula reaching up toward the crest of the vertebral column. The anterior limb has a short humerus; ulna and radius quite completely fused; the carpal bones form a transverse series, and the metacarpals and phalanges are in the common order. The pelvic girdle is connected to the vertebral column by the anterior ends of the long, slender ilia, which are about the same length as the urostyle. The ischium and pubic bone form together a compact structure, and with the posterior end of the ilium form the acetabulum, or socket, in which the head of the femur articulates. The femur is long and enlarged at both ends and is followed by the fused tibia and fibula. The tarsal bones are considerably elongated, two of them, the tibiale and fibulare, forming the principal part of this segment, the remaining tarsals being reduced. The metatarsals are followed by five series of digits.

The reproductive organs are most easily studied during the breeding season, at which time they become greatly enlarged. The ovaries are located dorsally in the abdomen and when gorged with eggs fill a large portion of the abdominal cavity. The ova

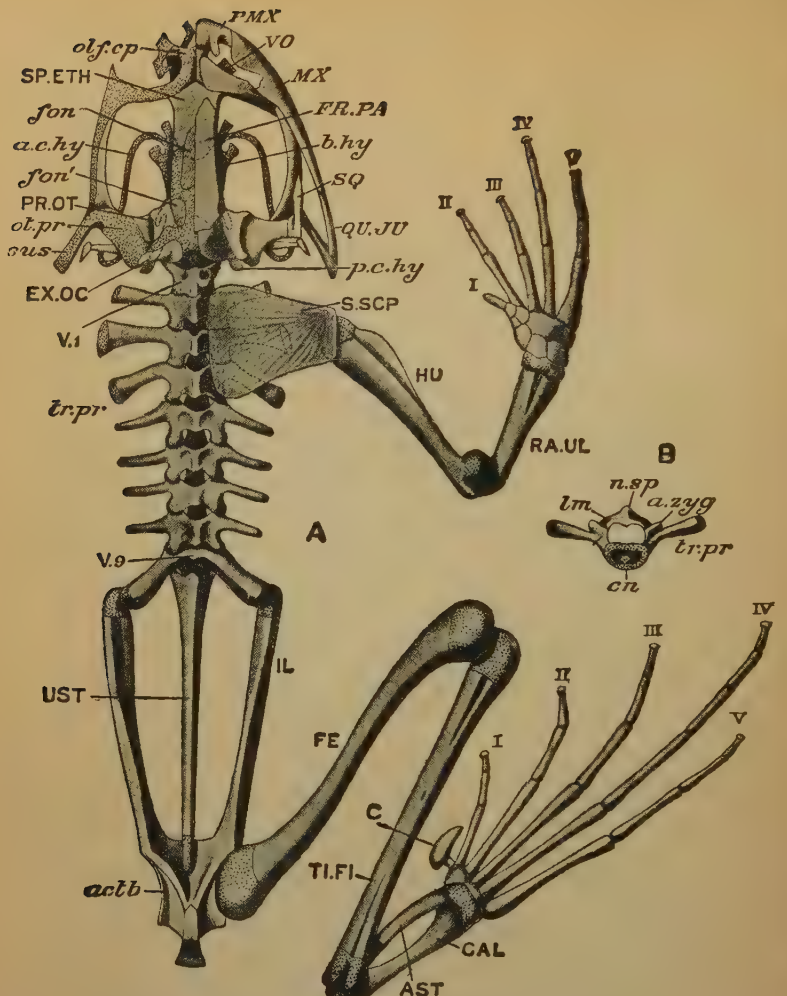


FIG. 229. — **Rana temporaria.** A, the skeleton from the dorsal aspect; the left half of the shoulder girdle and the left fore and hind limbs are removed, as also are the membrane bones on the left side of the skull. Cartilaginous parts dotted. Names of cartilage bones in thick, those of membrane bones in italic, capitals. *a.c.hy*, anterior cornu of hyoid; *actb*, acetabulum; **AST**, astragalus; *b.hy*, basi-hyal; **C**, calcar; **CAL**, calcaneum; **EX.OC**, exoccipital; **FE**, femur; *fon*, *fon'*, fontanelles; *FR.PA*, fronto-parietal; **HU**, humerus; **IL**, ilium; *MX*, maxilla; *ol.cp*, olfactory capsule; *ot.pr*, otic process; *p.c.hy*, posterior cornu hyoid; *PMX*, premaxilla; **PR.OT**, prootic; **RA.UL**, radio-ulna; **SP.ETH**, sphenethmoid; *SQ*, squamosal; **S.SCP**, suprascapula; *sus*, suspensorium; **TI.FI**, tibio-fibula; *tr.pr*, transverse process; **UST**, urostyle; **V.** *1*, cervical vertebra; **V.** *9*, sacral vertebra; *VO*, vomer; *I–V*, digits. B, the fourth vertebra, anterior face. *a.zyg*, anterior zygapophysis; *cn*, centrum; *lm*, lamina; *n.sp*, neural spine; *pd*, pedicle; *tr.pr*, transverse process. (After Howes, slightly altered.)

are discharged into the abdomen and taken up by the oviducts, the open ends of which communicate with the cavity. The ducts are long and coiled and become gorged with eggs during the process of oviposition. They terminate in large muscular structures, the uteri, and these open into the cloaca directly behind the opening of the urethra. The testes lie ventral to the kidneys and connect by means of delicate vasa efferentia with the urinary tubules. The spermatozoa, therefore, pass into the kidneys and are carried out by way of the ureters. The eggs as discharged are coated with a gelatinous substance that forms a large gelatinous mass on contact with water, which can frequently be observed floating at the surface of the water. The eggs are fertilized at the time of deposition, the male discharging spermatozoa over the eggs, and the sperm penetrating the covering of the egg outside the body. The development takes place within the egg until the tadpole has reached a considerable size and is able to move about with quite distinct contractions of the tail.

The growth and metamorphosis are very interesting as indicating the relationship of frogs and other amphibia. At first the tadpole is distinctly fish-like in form and has no appendages, but depends entirely upon movements of the tail for its locomotion. The head is blunt and the mouth rather narrow, and there are distinct, external gill filaments entending from the sides of the head, through which the blood courses to provide for respiration. As the tadpole grows, small bodies representing the hind limbs appear at the base of the tail, and these continue to grow, gradually taking on the form of legs of the frog. The front legs appear somewhat later than the hind legs and are at first included within the gill cavity, so that they reach some size before becoming visible on the outside. As these front legs grow, the external gills gradually diminish in size and function, finally disappear as gill appendages and are replaced by the true gills, resembling those of fishes. For a time the tadpole grows without much change of form, but after reaching the maximum size and about the time the legs become fully developed, the tail begins to shorten and is gradually absorbed, its substance

being taken up by the other tissues of the body, and it finally disappears so that only the termination of the vertebral column as seen in the adult frog is left. With the loss of the tail and the establishment of lung respiration, the frog crawls out of the water

FIG. 230. — **Rana temporaria**. Stages in the life history, from the newly hatched tadpoles (*1*) to the young frog (*8*). *2a* is a magnified view of *2*. (From Mivart.)

and gains its terrestrial existence. It appears at first smaller than the tadpole from which it came, and grows somewhat gradually, not attaining the full size until two or three years of age.

It is of special significance in the development of the frog that it passes through stages which correspond first with some of the

fish-like forms and later with the salamander or newts, which possess four legs and a long tail, and finally have the tail absorbed. Our inference from this is that the frogs at some time in the past were derived from a salamander-like animal, and that, probably as a result of their terrestrial habit and change of locomotion, the tail was lost.

Frogs have a very distinct economic importance outside of the fact that great numbers of them are used in laboratories in the United States in universities, medical colleges, and schools for the purpose of illustrating the principles in biology. They are quite extensively used as an article of food, though this is more particularly true in some European countries, and there is a considerable market for them in the United States, especially in the larger cities, and it is almost certain that this demand will gradually increase, provided a sufficient supply is obtainable, as they form a very choice article of food. The hind legs, which are used in this manner, contain considerable masses of muscle, and this is of a very delicate flavor and is to be compared with young chicken as a table delicacy. There are extensive areas of swamp land where frogs flourish and where they might be cultivated in large numbers if some attention were given to providing the best conditions for their growth. No doubt much more extensive industries could be developed in this line with proper attention. The tadpoles, which develop in water, feed upon aquatic vegetation which is usually developed in great abundance and provides substance for development of an immense number of individuals. The mature frogs, on the other hand, feed upon insects, so that the food which they secure in the adult stage may be useless or in some cases distinctly detrimental to crops, and the frogs may serve a doubly useful purpose in destroying insect pests and providing a marketable product.

We may properly consider here the question of the development of the locomotory organs, which are the characteristic feature of the vertebrates from fishes to mammals. The presence of four segmented appendages, adapted for locomotion in various forms and showing distinct homology, raises the question as to

their mode of derivation. There have been two prevalent theories with regard to the primary origin of these structures: one that they represent modified branchial arches with a certain displacement toward the hinder portion of the body and the development of fin rays, joints, etc.; the other that these organs arose from the primitive fin fold extending along the side of the body, this fold being primarily the locomotory structure and by specialization reduced to two parts on each side, these furnishing the basis for the development of the appendages with all their varied structures. In the fishes these become specialized into swimming organs, the skeletal portion being reduced and the fin rays elongated. In the amphibia, which mark the transition from aquatic to terrestrial habits, the appendages are elongated and articulated to form a definite leg and foot, and from this on the modifications into the different types of leg and arm are quite clearly indicated. This latter view has been supported by extensive studies in quite recent time and seems now to be much more firmly established than the other.

There is another problem which may be introduced if we attempt to determine the development of the power of flight or the modification of the anterior limbs into special organs for locomotion in the air. It is a striking fact that we have wings developed in three entirely distinct groups of vertebrates: the reptiles, birds, and mammals, and that in these three groups we have every reason to believe that the power of flight was developed independently, partly because of the quite different plan of structure into which the fore limb is modified, and partly because of the wide separation of the groups in which these organs appear. Birds and bats, while both equipped with very perfect organs of flight, have their structure so different that we cannot imagine the one to have been derived from the other; and the wing of the bat, while possibly more like that of the extinct flying reptiles, is still sufficiently different and the relations of these two groups so remote that common origin for the wing structure seems impossible. We may recall also the wings of insects, and with these

it is seen that there are four instances among animals in which the power of flight has been developed, distinct organs adapted for such locomotion evolved, and all of these along independent lines.

If we attempt to explain the modification of the fore limbs into wings, we are met by serious difficulties, since there is not sufficient record either in fossil forms, in intermediate stages of evolution of the organ, or in the embryological evidence, to demonstrate the precise path along which these organs have been developed, though there is abundant evidence that they have been modified from a pentadactyl organ strictly homologous with the fin, arm, or fore leg in other vertebrates.

The amphibians are divided into two main divisions, on the basis of the presence or loss of the tail. The first division includes the salamanders and newts, and the second division the frogs and toads.

It appears evident from the more specialized conditions of the tailless forms that these follow the tailed amphibians in the natural arrangement of the groups.

Caudata. — In this division the vertebræ in the tail region remain throughout life, and the body is elongate. The legs are nearly equal in length and not adapted for jumping. The gills in most cases are absent in the adult stage but in a few forms remain persistent and functional in the adult stage, which retains its aquatic habit.

The mud puppy is found in ponds and lakes of northeastern United States and is interesting because of its persistent aquatic habit. The external gills remain as distinct appendages at the side of the neck and are conspicuous, being of a bright red color during the life of the animal. The skin is soft and leathery and is somewhat folded. The animal is about a foot in length, with a broad flat head and wide mouth. It is a rather repulsive-looking creature, but quite harmless and of particular interest on account of its retaining the primitive aquatic structures.

The hellbender, another aquatic form, differs from the mud

puppy in the loss of the external gills and development of the lungs with the retention of the gill slits, although it does not take on the terrestrial habit. It is from fifteen to twenty-four inches in length and is found in waters of the Ohio river system, and has no particular economic value.

The salamanders are the most familiar forms, as they are found around houses and cellars and damp places, and may be recognized by the soft skin; most of those common around houses are nearly black with yellow or whitish spots. They are frequently called "lizards," but differ entirely from the true lizard in the absence of scales and the method of development, which is through a tadpole stage similar to that of frogs. The skin secretes a milky fluid which is discharged when they are irritated and which is somewhat acrid in character, but not so poisonous as to make it dangerous to handle them. One of the species of *Amblystoma* shows a peculiar modification in its development in the high plateau regions of the Rocky Mountains. The adult terrestrial form is not reached, but the animal remains in the aquatic larval stage and reproduces in this form. This is doubtless an adaptation to the dry region, the adult not having suitable conditions for survival. This may be interpreted as a suppression of the adult form without the suppression of the development of the reproductive organs. When these plateau forms are transported to other localities, they develop on into the adult terrestrial stage, as in the case of our eastern form.

Ecaudata. — This division includes the forms in which the tail is lost and the tail vertebræ fused into one long slender bone, the urostyle, the hind legs elongated and fitted for jumping. The frogs, tree toads, and toads are familiar forms; and we have already given in detail the characters of the common frog. The tree frogs and tree toads are similar forms. They are found commonly on the branches of trees and have the quite striking property of changing the color to harmonize with the surface on which they are resting. They have a very characteristic chirp, which is quite noticeable during summer evenings. They catch

insects and may be considered as serviceable in their general habits.

The common garden toad is a large, thick, rather heavy species, active during the night time and mostly quiet and hidden away during the day. The surface of the body is covered with numerous wart-like swellings, and from these there is some exudation from

FIG. 231. — Toad, **Bufo lentiginosus americanus**, on sand, showing protective marking and coloration. (Photograph by author.)

the gland cells included in the wart. Toads are, however, entirely harmless and may be handled with impunity. Their color depends much upon the color of the soil and materials on which they live, in some cases being quite dark and in others much lighter. In a variety occurring on beaches and sand dunes the skin is light and minutely speckled, so that it corresponds

closely with the sand on which it lives. It is, however, quite inclined to bury itself in the sand during the day, either burying itself completely or leaving a small surface of the back exposed. Toads feed very persistently upon insects and should be considered as a most valuable assistance in keeping the destructive insects in check. If their stomachs are examined, they will almost invariably be found gorged with insects and a large proportion of the insects eaten are destructive species, which would be distinctly injurious to crops. Like the frog, the toad deposits its eggs in water, but is not aquatic in its own habits in the adult stage and is seldom found in the water except at the time of egg deposition.

Another group, differing much from the other two groups already mentioned, is the Gymnophiona, which includes some very slender, snake-like forms occurring in Central and South America. These are distinguished by the absence of legs, but are separated from the snakes at once by the absence of scales. They burrow into the ground, making distinct nests in which they deposit a considerable number of eggs, the development being specialized, the larvæ passing through a stage corresponding with the tadpole without actually entering the water.

The economic importance of the amphibians has been considered in connection with the different common forms, and it need only be added that the species as a rule may be regarded as essentially useful and may all be protected as far as it is possible to do so. In order to encourage them to the best advantage, it is necessary that they should have suitable breeding ponds and that the tadpole stage should have sufficient opportunity to develop without exposure to fishes and other aquatic animals.

CHAPTER XVIII

Class Reptilia

The reptiles constitute one of the large and conspicuous groups of animals and possess on the whole very characteristic features, the living forms being distinctly terrestrial in habit, most of them creeping or dragging the body on the ground, and very few of them being able to walk with the body elevated. Their body surface is covered with scales or bony plates, they have pulmonary respiration even in those species occurring in water, and none of them pass through a gill breathing stage in their development. They belong to the species of animals in which respiration for the developing embryo is accomplished by means of an outgrowth of the alimentary tract called the allantois, in which there is an abundant circulation of blood, and through which the oxygen for the body tissues is derived. In reptiles, as in birds, embryonic development occurs in the egg, which is usually of large size, including a large amount of yolk, and the animal reaches a considerable size before hatching. In a few instances, where the young are brought forth alive, there is no connection with the oviducts, and as nutrition is secured by means of the yolk mass secreted previously by the adult, development is essentially the same as in other reptiles or in birds, and not strictly viviparous as in mammals. This is termed **ovoviviparous,** to distinguish it from the viviparous type of development.

The skeleton possesses many features showing the relationship to birds, and except in the matter of body covering and the different development of the front limbs the two groups must be considered as very closely related.

The group is divided into four distinct classes, and it will be

more satisfactory to consider a typical form of each one of these groups than to use any one form as a type for all.

The group is an old one, being represented in the Mesozoic age, which, on account of the abundance of the members of this group, was called the Reptilian Age. At that time the group included many gigantic species, some of them as much as sixty to eighty feet in length and of great height. Some of them walked on their hind legs and used the fore limbs evidently for the purpose of reaching the branches of trees, while in some other divisions there were well-developed wings apparently with a broad expanse of web, and presumably these forms could fly with considerable ease. They must have occupied in the Reptilian Age a similar position to that which the group of bats does at the present time. The present existing forms are mostly small, the largest being the alligator, while great numbers of smaller species, such as swifts and lizards, are but a few inches in length.

Order Lacertilia. — The lizards are, as a rule, small reptiles, with the legs well developed and the body covering consisting of small scales. Of the existing groups of reptiles they may be considered as the most generalized, and we may conceive that from some primitive form of this group the other orders have risen — the snakes by the reduction and loss of the legs, the turtles by the development of the carapace and plastron, and the crocodilians by specialization of the skin, teeth, stomach, heart, and structures especially connected with their aquatic life.

The skin in the lizards is flexible and the scales small, overlapping, and occurring over most of the body, the ventral surface as well as the upper parts being abundantly scaled. The head and body are connected by a distinct and usually rather short neck, and the mouth is not especially dilatable. The teeth are numerous, the feet are provided with four or five toes, and the tail is long and flexible. The eyes, usually small, are provided with eyelids, and the skeleton is characterized by numerous vertebræ, those of the pelvic region being united into a short sacrum, including sometimes three, but rarely more than two, vertebræ. The cer-

vical region includes about nine vertebræ, and the atlas is composed of three pieces, one ventral and two dorso-lateral. The centra of the vertebræ are either procœlous or amphicœlous, the former being the most frequent form. In a few forms, such as the geckos, the vertebræ are biconcave, and the notochord persists except in the central part. The sacral vertebræ are not completely fused, their movement is restricted, and the caudal vertebræ present a peculiar feature in that the central section in each vertebra remains unossified. On this account the vertebræ are easily separated, and this accounts for the extreme ease with which the tail portion of the lizards may be broken into pieces, a feature which is perhaps a means of protection, assisting the animal to escape from its enemies. Most of the lizards are oviparous, but a few, such as the horned toads, are viviparous. Their food consists mainly of insects, worms, and small animals of different kinds, a few being quite strictly herbivorous. The group is represented abundantly in the tropical regions, but the species diminish rapidly as we pass into the temperate regions in either direction.

The swifts, skinks, and ground lizards are familiar examples in the Southern States, and the horned toads occur abundantly in the plains regions and throughout the arid parts of the southwestern United States. These latter are interesting creatures in their adaptation to desert life, being able to resist dryness in an extreme degree and surviving for long periods without food. They are provided with numerous short spines, and their color protects them by its close resemblance to the gravel or sand upon which they live. They are entirely harmless, insect feeding, and except as curiosities have no particular economic importance. In tropical countries the iguanas occur in abundant forms, some of these being large and reaching a length of from four to five feet. The Gila monster occurring in Arizona and southern California is reputed to be venomous, its bite accompanied by an ejection of poison producing a dangerous wound. The chameleons of the Old World are noted for their remarkable ability to change their

color to blend with their surroundings, and also for the extremely long flexible tongue which can be darted out to a distance of several inches for the capture of food. An interesting native species is the glass snake, sometimes called the joint snake, which unlike other lizards is legless, the limbs being very much reduced and entirely concealed within the skin. They may be separated from the snakes, however, by the small scales on the under side of the body and the character of the jaws. They break to pieces readily, especially in the caudal region, and it is this peculiarity which has given them the name of joint snake. Needless to say, the vertebræ once separated do not grow together again; but the tail may be regenerated in the course of time, although usually remaining shorter and more stumpy than the original one. Most of the lizards have little economic importance except as they feed upon insects, but a few are used as food.

Order Ophidia. — This group includes the snakes or serpents, the most striking characters of which are the absence of legs and the long slender body. The head is often flattened and the jaws are capable of great distention, so that animals of much larger size than the snake may be swallowed. The body is covered with small overlapping scales for all of the dorsal portion and the ventral surface is covered with broad plates, the ventral scutes or **gastrosteges**. These are usually of a single piece, but in some species the plate overlapping the anus is divided into two parts, and the plates posterior to the anus are quite commonly divided. The scales on the head have definite shapes and are much used in separation of the species. The tongue is long and slender and usually forked, either black or red in color, and may be darted out a considerable distance. Owing to a groove in the lower jaw the projection of the tongue may occur without opening of the mouth, and it is often thrust out in a somewhat threatening manner. The jaws are broad, with teeth directed backward, and these aid in advancing the food masses into the alimentary canal, the jaws being advanced alternately and the teeth fixed. The stomach is long and but slightly marked off from the other

divisions of the canal. The lungs are much modified, one, usually the right, being very much reduced, while the opposite lung is elongate, occupying a considerable space in the central body region and extending posteriorly into a large air sac. The circulation is on the typical reptilian pattern; but the distribution of the arteries, as well as the position of the kidneys, liver, and other portions of the viscera, is distinctly adapted to the elongate form. Locomotion is a distinct adaptation, the legs being entirely lost in most forms or present as mere rudiments within the anal space in some cases. Progression may be of three types, all, however, based upon the lateral muscles, the intercostal muscles, which form extensive bands along the side of the body. These attach to the ribs, which connect at their tips with the ventral scutes and serve as a base of motion. If the ribs are advanced alternately so that they assume a walking motion, the body is thrown into slight undulations, the scutes by their contact with the ground serving to push the body forward by slow alternate movements. The simultaneous advancement of the ribs of the same part serves to push the animal forward in a straight line, a movement probably less common than the preceding one; while the third mode of progression may occur by the fastening of the anterior scutes and the contraction of the body in broad curves so as to bring the tail near the head, when the straightening of the body pushes the head forward to secure a new base of attachment. The snake may strike or spring from a base formed by a coil of the tail, but it is unable to throw itself to any distance in this manner. Further, it may lift up the anterior part of the body with the tail portion as a base of contact, but it cannot raise more than half or two thirds of the body from the ground without the aid of some support. Trees may be climbed by embracing the trunk or branches with coils of the body, and many species of snakes are quite arboreal in habit. Most of the species nest on the ground, but there is a wide variation in places of activity, some being aquatic, others living among rocks, and others in grassy fields, and still others in thickets or in timber. In most

cases the eggs are deposited in nests fitted for their reception but in a few cases the young are brought forth alive.

Snakes as a rule feed upon mice, toads, frogs, and other small animals, and while some of these are serviceable, it may be considered that on the whole snakes serve a useful purpose rather than being injurious, and deserve protection. A few species which are poisonous must of course be considered as too dangerous in this connection to be protected for the sake of the benefit

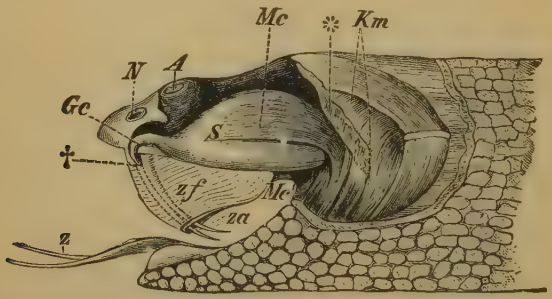


FIG. 232. — Poison apparatus of rattlesnake. *A*, eye; *Gc*, poison duct entering the poison fang at †; *Km*, muscles of mastication partly cut through at *; *Mc*, masseter or constrictor muscle; *Mc'*, continuation of the constrictor muscle to the lower jaw; *N*, nasal opening; *S*, fibrous poison sac; *z*, tongue; *za*, opening of the poison duct; *zf*, pouch of mucous membrane inclosing the poison fangs. (From Wiedersheim.)

that they may give in the food they capture. Of the poisonous forms, the rattlesnake and copperhead are the most serious ones occurring in the United States; but in tropical regions many extremely venomous species occur, the fer-de-lance of the West Indies and the cobra of India being especially fatal in their attacks. The venomous species possess strong fangs, which are lifted when the animal strikes and which are provided with a groove or canal along which the venomous secretion from the poison glands is carried into the wound.

The inherent dislike for snakes of all kinds, and the tendency to destroy everything bearing this form, is perhaps based upon the poisonous character of some of the species most commonly

known in the early history of the human race, and the prejudice is so widespread at present that few people can resist the inclination to kill every snake they meet. A knowledge of their habits and usefulness, however, should be sufficient reason to protect all of the non-poisonous forms. Many of the snakes are kept in menageries and zoological gardens, and such large forms as pythons,

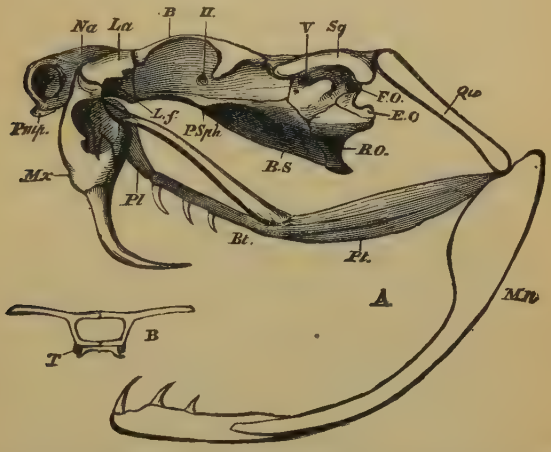


FIG. 233. — A, lateral view of skull of rattlesnake, **Crotalus**. *B.O*, basi-occipital; *B.S*, basi-sphenoid; *E.O*, exoccipital; *F.O*, fossa ovalis; *La*, conjoined lachrymal and prefrontal; *L.f*, articulation between lachrymal and frontal; *Mn*, mandible; *Mx*, maxilla; *Na*, nasal; *Pl*, palatine; *Pmx*, premaxilla; *P.Sph*, presphenoid; *Pt*, pterygoid; *Qu*, quadrate; *Sq*, squamosal; *II.* *V*, foramina of exit of the second and fifth cranial nerves. B, transverse section at point lettered B in Fig. A; *T*, trabeculæ. (After Huxley.)

boa constrictors, and the venomous serpents have a commercial value for this purpose. The skins are used to some extent in manufactures, but aside from this the commercial value of snakes in general is small.

Of our common native species in the United States, the small green snakes, the abundant garter snakes, and the blowing viper or hognose snake, the black snake, and fox snake are quite harmless, and if one can overcome the natural antipathy they

will be found to have much of interest in their structure and habits.

Order Chelonia. — The turtles form a very well marked division of the reptiles, all possessing a large extension of the body covering, forming a protecting shell, the **carapace**, and underneath a broad, flat plate, the **plastron.** Divested of these parts and with the head and tail extended, they show much similarity to lizards in their general structure, and they stand evidently as a much specialized form derived from more primitive lizard-like ancestors. The carapace furnishes a protecting shield within which the head, tail, and legs may be contracted, and in this condition turtles are remarkably well protected against many of their enemies. They depend upon this shell rather than upon any swift movement for their means of escape. The head is short and thick, the jaws horny and without teeth, the tongue short and the eyes provided with lids, the neck long and capable of doubling together in a close S-shape form, so that the head may be drawn back within the carapace. The carapace consists of broad bony plates developed in the skin, and termed dermal bones; but these bones are fused with the neural spine along the vertebral column, and with the ribs along the sides, so that it is a composite structure. It is covered with tough leathery or horny plates which have a distinct pattern in the different groups, and which in their arrangement have no agreement with the arrangement of the bones on which they lie. The margins of the carapace are formed of dermal bones, and there is usually a strong bony bridge connecting the carapace with the plastron, the latter being formed of the dermal bones of the ventral surface. The horny plates of the plastron have a constant arrangement for the different families or genera, and like those of the carapace are serviceable in the separation of the groups. The horny covering found in the carapace is in some species highly developed and in the tortoise-shell turtles becomes a very valuable article, being used very extensively in the manufacture of combs and ornaments.

The skeleton of the turtles, so far as the vertebral column is concerned, approaches that of the lizards and shows certain points of specialization which should be noticed. The skull is somewhat like that of birds in the tendency toward fusion of the bones and

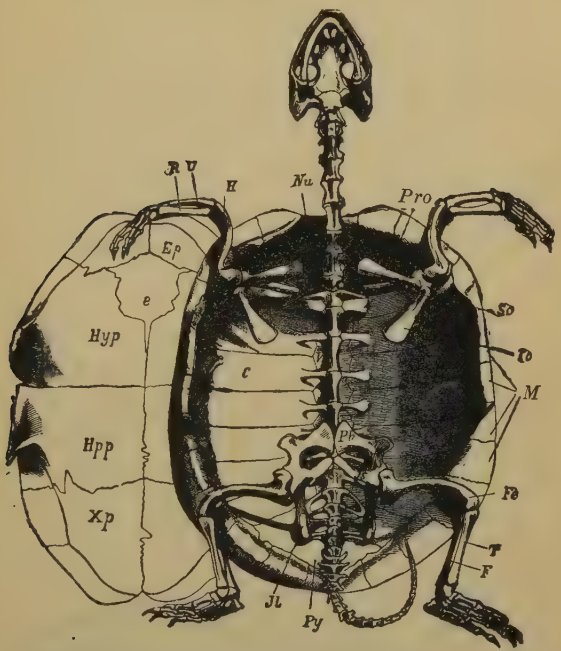


FIG. 234. — **Cistudo lutaria**. Skeleton seen from below; the plastron has been removed and is represented on one side. *C*, costal plate; *Co*, coracoid; *e*, entoplastron; *Ep*, epiplastron; *F*, fibula; *Fe*, femur; *H*, humerus; *Il*, ilium; *Is*, ischium; *M*, marginal plates; *Nu*, nuchal plate; *Pb*, pubis; *Pro*, pro-coracoid; *Py*, pygal plates; *R*, radius; *Sc*, scapula; T, tibia; *U*, ulna. (From Zittel.)

in the absence of teeth. The cervical vertebræ are very loosely articulated, and the articulation between the last cervical and the first dorsal permits of a rotation of nearly 180 degrees, so that when the head is retracted this vertebra lies nearly parallel to the dorsal. The dorsal vertebræ by their neural spines are fused

into the carapace, and the ribs with the dermal plates, while their tips instead of connecting to a sternum are fused with marginal dermal bones of the carapace. The pectoral girdle is connected by the coracoids, which are pillar-like, with the floor of the plastron, there being no sternum, and the pelvic girdle and plastron are similarly connected by the pubic bones. The sacrum is short and not particularly fused, and is succeeded by a number of caudal vertebræ, which taper rather rapidly to a minute terminal one. In the circulation, digestive system, and reproductive organs turtles resemble lizards, but in respiration they present a specialized condition associated with the rigidity of the ribs, inspiration being performed by a swallowing process. There is a slight development of diaphragm. The lungs are spacious and respiration sluggish, the species occurring in water being able to remain submerged for long periods. In the soft-shelled turtles, which are quite completely aquatic in habit, there is a special provision for aquatic respiration, the throat being provided with numerous folds which are richly supplied with blood vessels and in which by the inflow and outflow of water the blood is oxygenated. Professor Gage has shown that this turtle may survive with this means of respiration without the frequent movements to the surface which are necessary in the other species. In reproduction the turtles are all oviparous and their eggs are deposited in earth or sand. The species which are aquatic or semi-aquatic in habit migrate to adjacent banks of streams or ponds for the deposition of their eggs, forming nests near the surface of the ground in which a considerable number of eggs are deposited. The eggs are protected by tough membranous shells somewhat stiffened by deposits of lime, but usually less rigid than the eggs of birds.

In habits the turtles show a wide range, from the species which are restricted to dry land to those which are constant residents in water, leaving this medium only for the deposition of eggs. They vary much in shape, some of the species being provided with high arched carapace, and others, like the mud turtle and

soft-shelled turtles, with flattened carapace. All are sluggish in their movements, the body being dragged in moving, and their sole protection on the approach of danger being to retract the exposed parts within the carapace. While the aquatic species vary in some respects, it is probable that the extremely aquatic forms, as well as the subterranean and specialized dry land forms, should be looked upon as extremes of divergence from forms which are related to the lizards in general structure. On this basis the snapping turtle may perhaps be considered as representing the most primitive form occurring in this region.

The common snapping turtle, or mud turtle, is a familiar and widely distributed form, used to some extent as food, and recognized as a ferocious species which must be handled with care to avoid its powerful beak. It is semi-aquatic and in water depends upon catching aquatic animals as its food. The alligator snapper of the Gulf region occurs in fresh waters and reaches a large size, individuals measuring two feet or more in length of carapace. The various species of tortoise and terrapin are somewhat more terrestrial, and some of these, especially the terrapin, are highly prized as food. The sea turtle, or green turtle, and tortoise-shell turtle, which are marine in habit, coming to land for deposition of eggs, have a distinct commercial value both as food and for the tortoise shell derived from the carapace. The soft-shelled tortoises are fresh-water forms which have been mentioned as showing extreme adaptation to aquatic life. They are carnivorous and quite ferocious in their habits. The carapace and plastron are soft and leathery, the dermal bones being slightly developed, and this feature may be looked upon either as primitive or as an instance of reduction due to modification in habit. The ribs which approach the leathery carapace extend outward to the margins, and their distribution would seem to indicate a former association with more complete dermal structure. While nearly all commercial use of turtles is based upon the capture of individuals in their native habitat, it seems quite certain that some attention to furnishing them with favorable

conditions in the localities in which they naturally grow might result in a much greater supply, and that they might thus form a basis for a still more important industry. The marine forms, of course, except as they come to shore for breeding, are beyond any such control; but the terrapin and some others of our swamp-living species might very well be utilized on a commercial basis.

Order Crocodilia. — The alligators or crocodiles are aquatic reptiles and represent of living forms the most complete adaptation to aquatic life. They are mostly of large size, and among the most powerful of the reptilians, and show many very interesting and special adaptations. The body is covered with a very tough hide and further provided with numerous bony plates and horny protecting covering, but the plates are not fused, as in the turtles, to form a rigid carapace. The body is elongated, lizard-like in shape, and the group may be looked upon as derived from some primitive lizard-like ancestor. The head is elongated and the jaws are much extended and provided with numerous teeth firmly implanted in the jaw bones. The legs are adapted for swimming and crawling, and a long, powerful tail is used both for locomotion in water and for offense and defense on the shore. The eyes possess eyelids and a nictitating membrane, while the ears and nostrils are provided with cuticular folds by which they may be closed to exclude water while the animals are beneath the surface. The position of these structures on the head is such that ears, eyes, and nostrils may all be exposed above the surface of the water while practically the whole head is submerged. The mouth is provided with a structure which excludes water from the esophagus, so that the prey may be dragged under water and drowned without danger of water entering the alimentary canal. The stomach is bird-like in character, provided with a strong muscular portion, suggesting the gizzard; and the circulation is a distinct departure from that of other reptiles in the division of the ventricle into two chambers, thus reaching the same condition of four-chambered heart which is present in birds and mammals. It should be noted, however, that the four-chambered condition in birds and mam-

mals cannot be traced as a derivation from these animals, and this occurrence here is an interesting coincidence, showing the tendency to separation of the blood supply belonging to the systemic and pulmonary circulations. In crocodilians, however, the advantage of separation secured by the formation of two ventricular chambers is partially lost, owing to the fact that one of the aortic arches and the pulmonary artery arise from the right ventricle. Doubtless, however, the systemic and pulmonary blood supply is kept much more completely separated than is the case in lizards and turtles.

Crocodilians belong to the tropical regions of the earth and are represented by the alligators of southern United States, the crocodiles of North and South America and Africa, and the gavials of southern Asia. The Mississippi River alligator of our southern Gulf States is one of the largest living species, reaching a length of from twelve to fifteen feet, and is possessed of great strength. Its hide is very valuable, being utilized in the manufacture of numerous articles, requiring durability along with beauty of marking. The rapid destruction of these animals for the sake of hides and because of their destructive nature has gradually reduced their numbers and threatens a complete loss of the industry based upon alligator hides, unless means are taken to preserve them in certain favorable localities and give them the necessary conditions for their multiplication. Some tracts in the Gulf States might perhaps be of much greater value in the shape of alligator farms than if devoted to any other purpose.

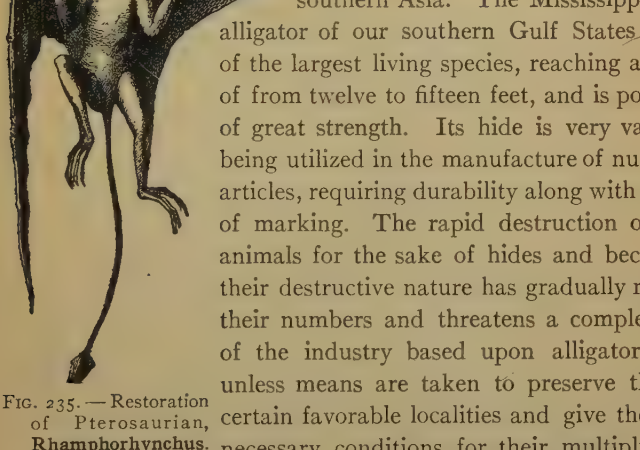


FIG. 235. — Restoration of Pterosaurian, **Rhamphorhynchus**. (After Zittel.)

Some most interesting forms of reptiles occurred in earlier

geological periods and represented wide diversity of habit, some of them being provided with wings and doubtless being able to make extensive flights; others, land animals of immense size, some of them from eighty to one hundred feet in length, some provided with strong hind legs and such weak or small fore legs that they very evidently used the hind legs only in locomotion, and still others in great numbers that were aquatic in habit, some of them reaching enormous size. The study of these, while belonging properly to Paleontology, is of great interest as indicating the lines of adaptation followed in past periods.

CHAPTER XIX

Class Aves

The group of birds presents a number of very striking features in structure and habit, and, especially in their ability to live in the air, have surpassed all other groups of animals. They show, however, adaptation to a very wide range of conditions, many being aquatic, others terrestrial, others arboreal, and different species are adapted to a wide range of food and of temperature. Birds are distinguished at once from all other animals by the body covering of feathers, as no other animal possesses this particular kind of structure. They also differ in the character of the wings, for while not the only animal capable of flight, no other possesses wings of the same structure.

Existing birds have the mouth provided with a strong beak without teeth, but many extinct forms were provided with teeth, and the absence of teeth may be considered as resulting from reduction accompanying the development of the beak. The fore limbs are adapted especially for flight, and except in a few running birds and certain aquatic species possess an expanse of surface due to the long feathers which enables them to fly readily. The hind limbs, which in some forms are used for resting on the ground, are in aquatic forms fitted for swimming, and in perching birds especially adapted for grasping the branches of trees. The toes are usually four in number, and in most cases three are directed forward and one backward.

The digestive system shows special structures in the case of grain-eating forms, the esophagus being followed by a large, capacious crop, and this by a very muscular gizzard which serves

as the grinding organ, inclosing pebbles and other hard substances which doubtless serve in the grinding of the grain.

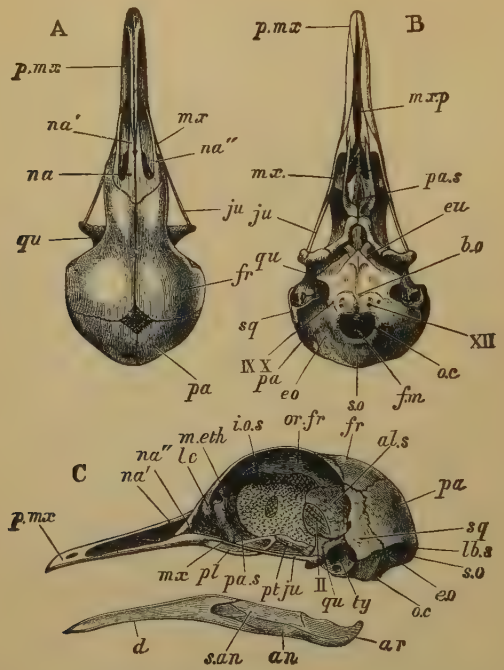


FIG. 236. — **Columba livia**. Skull of young specimen. A, dorsal; B, ventral; C, left side; *al.s*, alisphenoid; *an*, angular; *ar*, articular; *b.o*, basi-occipital; *d*, dentary; *e.o*, exoccipital; *eu*, aperture of Eustachian tube; *f.m*, foramen magnum; *fr*, frontal; *i.o.s*, interorbital septum; *ju*, jugal; *lc*, lachrymal; *lb.s*, lambdoidal suture; *m.eth*, mesethmoid; *mx*, maxilla; *mx.p*, maxillo-palatine process; *na*, *na'*, *na''*, nasal; *o.c*, occipital condyle; *or.fr*, orbital plate of frontal; *pa*, parietal; *pa.s*, parasphenoid (rostrum); *pl*, palatine; *p.mx*, premaxilla; *pt*, pterygoid; *qu*, quadrate; *s.an*, supra-angular; *s.o*, supraoccipital; *sq*, squamosal; *ty*, tympanic cavity; II–XII, foramina for cerebral nerves. (From Parker's *Zoötomy*.)

The circulation shows a distinct advance over that of the reptiles, the heart having four chambers, and the pulmonary and systemic circulation being entirely distinct. But one aortic arch

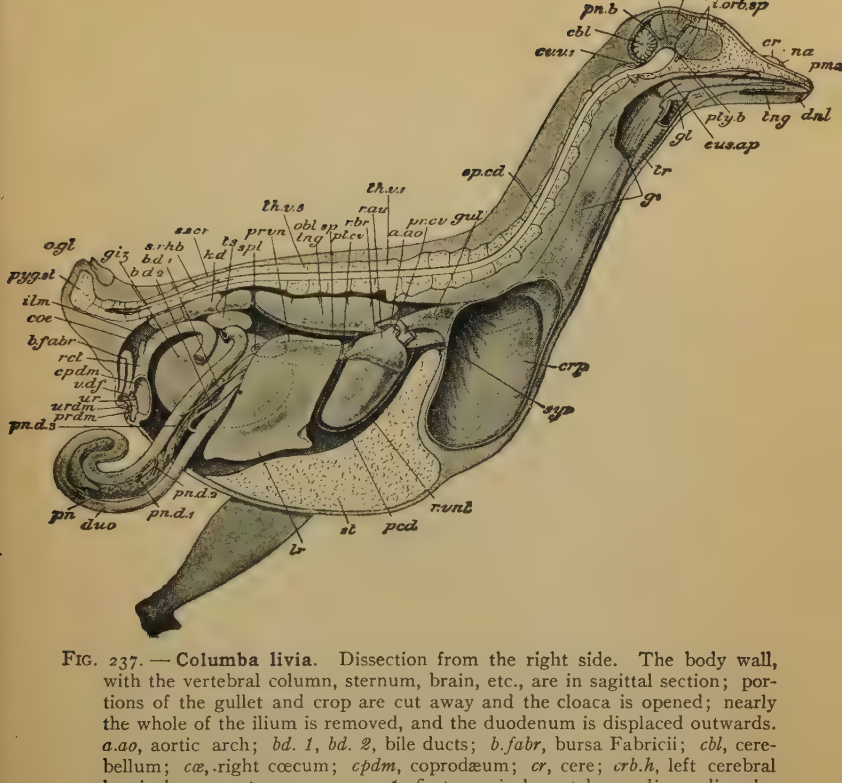


FIG. 237. — **Columba livia.** Dissection from the right side. The body wall, with the vertebral column, sternum, brain, etc., are in sagittal section; portions of the gullet and crop are cut away and the cloaca is opened; nearly the whole of the ilium is removed, and the duodenum is displaced outwards. *a.ao*, aortic arch; *bd. 1*, *bd. 2*, bile ducts; *b.fabr*, bursa Fabricii; *cbl*, cerebellum; *cæ*, right cœcum; *cpdm*, coprodæum; *cr*, cere; *crb.h*, left cerebral hemisphere; *crp*, crop; *cr.v. 1*, first cervical vertebræ; *di.cæ*, diacœle; *dnt*, dentary; *duo*, duodenum; *eus.ap*, aperture of Eustachian tubes; *giz*, gizzard (dotted behind the liver); *gl*, glottis; *gul*, gullet; *ilm*, ilium; *i.orb. sp*, interorbital septum; *kd*, right kidney; *lng*, right lung; *lr*, liver (right lobe); *na*, bristle passed from nostril into mouth; *obl.sep*, oblique septum; *o.gl*, oil gland; *pcd*, pericardium; *pmx*, premaxilla; *pn*, pancreas; *pn.b*, pineal body; *pnd. 1–3*, pancreatic ducts; *pr.cv*, right precaval; *prdm*, proctodæum; *prvn*, proventriculus (dotted behind liver); *pt.cv*, postcaval; *pty.b*, pituitary body; *pyg.st*, pygostyle; *r.au*, right auricle; *r.br*, right bronchus; *rct*, rectum; *r.vnt*, right ventricle; *sp.cd*, spinal cord; *spl*, spleen (dotted behind liver); *s.rhb*, sinus rhomboidalis; *s.scr*, synsacrum; *st*, carina sterni; *syr*, syrinx; *th.v. 1*, first, and *th.v. 5*, fifth, thoracic vertebræ; *tng*, tongue; *tr*, trachea; *ts*, right testis; *ur*, aperture of left ureter; *urdm*, urodæum; *v.df*, aperture of left vas deferens. (After Parker and Haswell.)

persists, and this the right instead of the left. Usually, also, one carotid artery is reduced — a feature perhaps associated with the elongate neck and small size of the head. The lungs are well

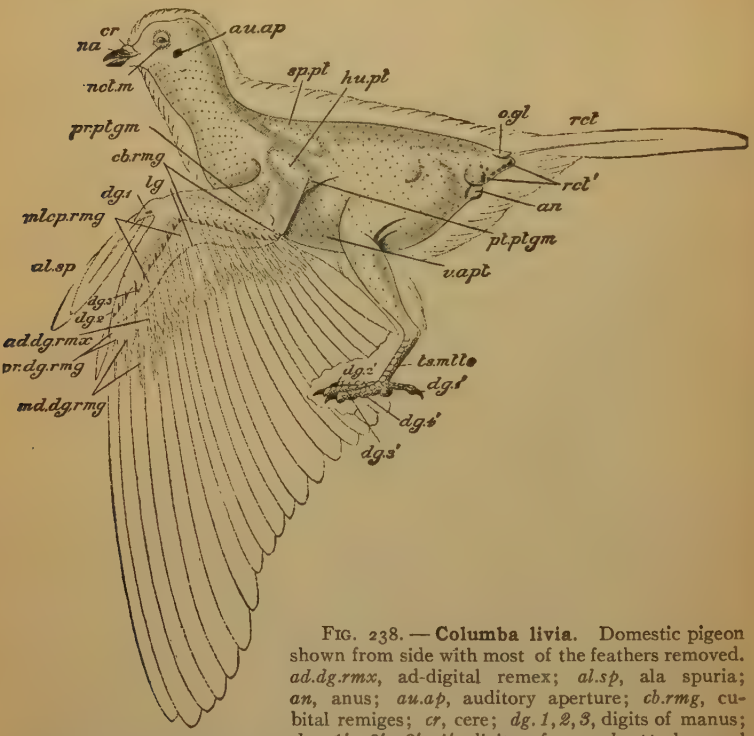


FIG. 238. — **Columba livia.** Domestic pigeon shown from side with most of the feathers removed. *ad.dg.rmx*, ad-digital remex; *al.sp*, ala spuria; *an*, anus; *au.ap*, auditory aperture; *cb.rmg*, cubital remiges; *cr*, cere; *dg. 1, 2, 3*, digits of manus; *dg. 1′, 2′, 3′, 4′*, digits of pes; *hu.pt*, humeral pteryla; *lg*, ligament of remiges; *md.dg.rmg*, mid-digital remiges; *na*, nostril; *nct.m*, nictitating membrane; *o.gl*, oil gland; *pr.dg.rmg*, pre-digital remiges; *pr.ptgm*, pre-patagium; *pt.ptgm*, post-patagium; *rct*, mesial rectrix of right side; *rct′*, sacs of left rectrices; *sp.pt*, spinal pteryla; *ts.mtts*, tarso-metatarsus; *v.apt*, ventral apterium, or featherless space. (After Parker and Haswell.)

developed, and there are in addition a number of air sacs connected with them which permit the retention of considerable quantities of air. The respiration differs from that of mammals

on account of the absence of a diaphragm and the respiratory mechanism of the thoracic walls, the active movement of respiration being the expiration caused by the drawing of the sternum toward the backbone, while inspiration results from relaxation of the muscles and the springing back of the sternum. This action is something like that of a pair of bellows. The trachea is pecul-

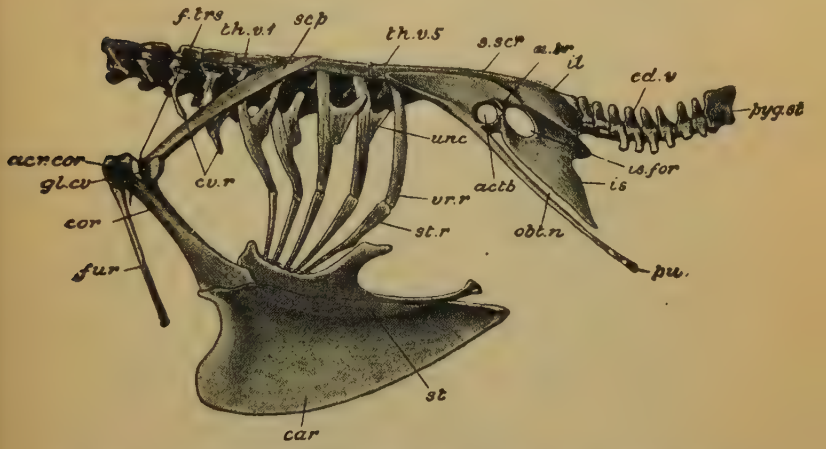


FIG. 239. — Domestic pigeon, **Columba livia**. The bones of the trunk. *acr. cor*, acrocoracoid; *a.tr*, anti-trochanter; *actb*, acetabulum; *car*, carina sterni; *cd.v*, caudal vertebræ; *cor*, coracoid; *cv.r*, cervical ribs; *f.trs*, probe passed into foramen triosseum; *fur*, furcula; *gl.cv*, glenoid cavity; *il*, ilium; *is*, ischium; *is.for*, ischiatic foramen; *obt.n*, obturator notch; *pu*, pubis; *pyg.st*, pygostyle; *scp*, scapula; *s.scr*, syn-sacrum; *st*, sternum; *st.r*, sternal ribs; *th.v. 1*, first, and *th.v. 5*, last, thoracic, vertebræ; *unc*, uncinates; *vr.r*, vertebral ribs. (After Parker and Haswell.)

iar in having cartilaginous rings which slip upon each other so that even when the neck is stretched the tracheal tube has a continuous rigid wall and cannot be easily compressed. Another striking feature connected with the respiratory system is the location of the voice box, which is at the lower end of the trachea where it separates into the bronchi. This is called the **syrinx**, but corresponds in function with the larynx of mammals. Many

birds possess quite a complicated syrinx and a high development of the vocal organ, which may be noted as especially prominent in the best singers, such as the thrushes, catbirds, mocking birds, and some sparrows. The nervous system is on the same plan as

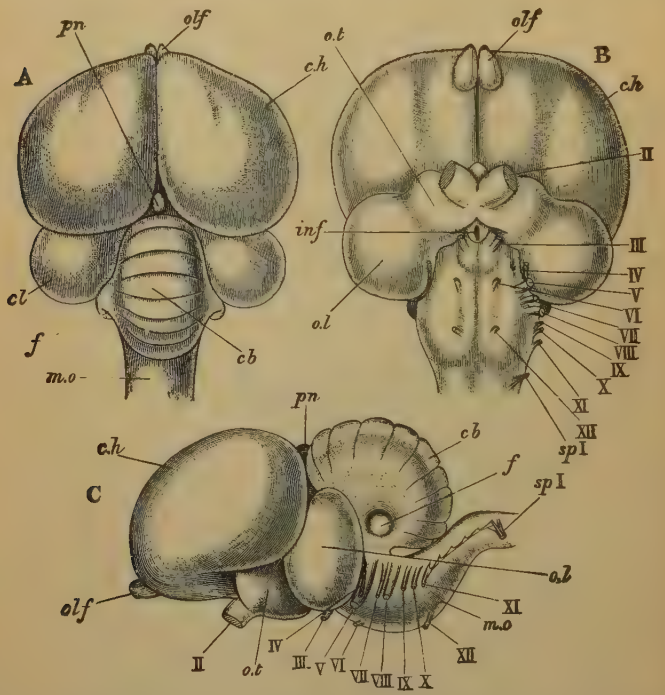


FIG. 240. — **Columba livia**. The brain; A, from above; B, from below; C, from the left side. *cb*, cerebellum; *c.h*, cerebral hemispheres; *f*, flocculus; *inf*, infundibulum; *m.o*, medulla oblongata; *o.l*, optic lobes; *o.t*, optic tracts; *pn*, pineal body; II–XII, cerebral nerves; *sp. 1*, first spinal nerve. (From Parker's *Zoötomy*.)

the reptiles, but there is a much larger development of cerebrum and cerebellum. The latter is strongly convoluted. The eye, which in most birds is very perfect, is peculiar in the development of the **pecten**, a process attached to the retina, near the

entrance of the optic nerve. An interesting provision occurs in the development of different centers of acute vision for near and distant objects.

In reproduction the birds are similar to the reptiles in that the eggs are large and contain a great deal of yolk material, so that the embryo reaches an advanced stage of development before hatching. The ovaries are modified, one of them becoming reduced

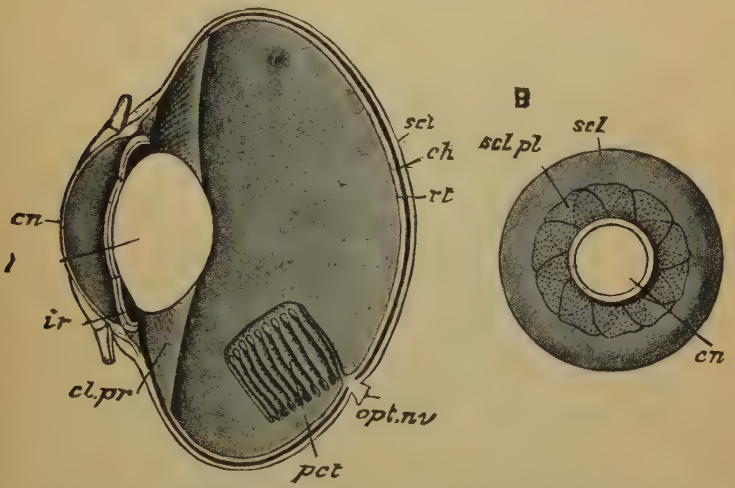


FIG. 241. — The eye. A, in sagittal section; B, the entire organ, external aspect; *cn*, cornea; *ch*, choroid; *cl.pr*, ciliary processes; *ir*, iris; *l*, lens; *opt.nv*, optic nerve; *pct*, pecten; *rt*, retina; *scl*, sclerotic; *scl.pl*, sclerotic plates. (After Vogt and Yung.)

and the other developing so as to occupy a median position just beneath the vertebral column. The single large oviduct enlarges posteriorly, and is supplied with glands which secrete the albumen that surrounds the yolk mass and with the shell glands which produce the shell first as a delicate membrane, and then exterior to this a hard calcareous deposit which gives the egg its rigidity. In the male both testes are developed, and the vasa deferentia extend backward, terminating in the cloaca.

From the formation of the egg noted above it will be seen that the bird's egg is a somewhat complicated structure, the large central yolk being covered by a number of other structures. The yolk itself is composed of a series of concentric layers, inclosing at the center a small non-coagulable fluid, while on the surface of the yolk at one point is located the germinal vesicle, which includes the nucleus of the egg cell. The yolk is included within a delicate

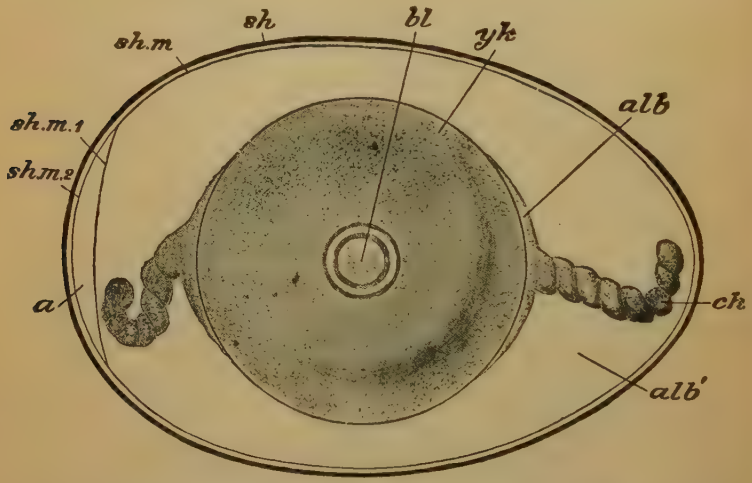


FIG. 242. — **Gallus bankiva** (domestic fowl). Semi-diagrammatic view of the egg at the time of oviposition. *a*, air space; *alb*, dense layer of albumen; *alb'*, more fluid albumen; *bl*, blastoderm; *ch*, chalaza; *sh*, shell; *sh.m*, shell membrane; *sh.m. 1*, *sh.m. 2*, its two layers separated to inclose air cavity. (From Marshall's *Embryology*, slightly altered.)

vitelline membrane, and is suspended in the albumen by means of two semigelatinous cords, the **chalazæ**, which serve to permit rotation of the yolk in one plane and not in an indefinite number of directions. As a result of this rotation and the fact that the part of the yolk on which the germinal vesicle rests is of lighter specific gravity than the opposite portion, the germinal vesicle invariably assumes the position which is uppermost, and consequently approaches nearest to the body of the incubating bird.

Fertilization of the egg occurs in the upper part of the oviduct and before the addition of the albumen and shell, and the segmentation begins shortly afterward and proceeds very slowly, and may be almost completely retarded for a period after oviposition and until incubation begins. With the beginning of the incubation process segmentation is accelerated, and formation of the germ layers and the growth of the embryo from the surface of the yolk proceeds. In case incubation has been deferred too long the segmentation process is suspended and the egg may be considered dead. A detailed study of the embryology of the chick is extremely interesting, and furnishes a most excellent example for the development of vertebrates. The principal steps in this development may be seen by a study of eggs at different stages, but an exhaustive study of the subject can best be pursued in a course of embryology.

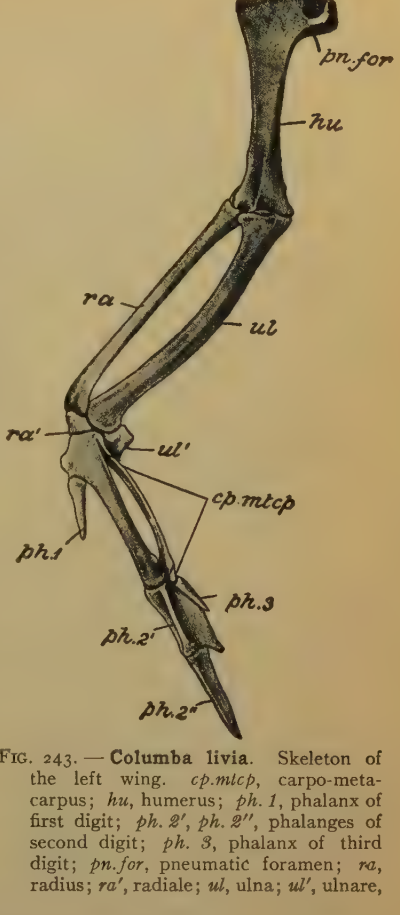


FIG. 243. — **Columba livia**. Skeleton of the left wing. *cp.mtcp*, carpo-metacarpus; *hu*, humerus; *ph. 1*, phalanx of first digit; *ph. 2'*, *ph. 2''*, phalanges of second digit; *ph. 3*, phalanx of third digit; *pn.for*, pneumatic foramen; *ra*, radius; *ra'*, radiale; *ul*, ulna; *ul'*, ulnare,

The mechanism of flight deserves especial mention, as there is a distinct modification in the arrangement of muscles for the performance of this function. The sternum is provided with a large

keel which forms the basis of attachment for the greatly developed pectoral muscles. The coracoid bone is much enlarged, pillar-like, and quite rigidly attached to the sternum, and supports at the other end the scapula. The attachment of the large pectoral muscle is upon the under surface of the humerus, and this accom-

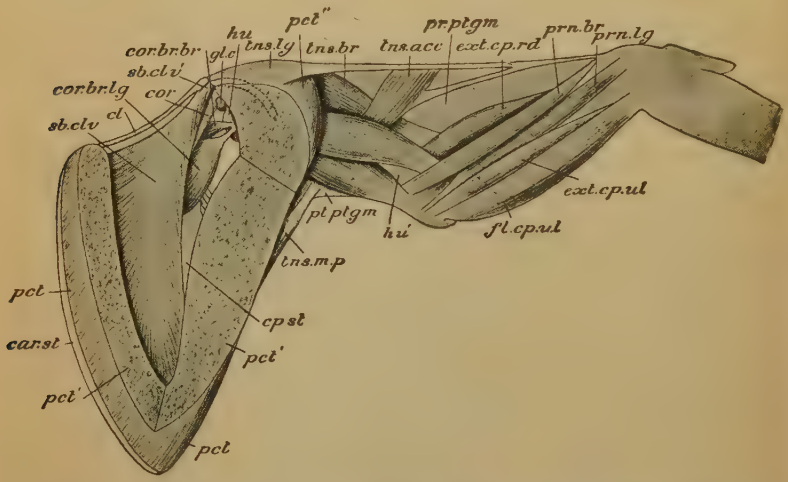


FIG. 244. — **Columba livia**. The principal muscles of the left wing; the greater part of the pectoralis (*pct*) is removed. *car.st*, carina sterni; *cl*, furcula; *cor*, coracoid; *cor.br.br*, coraco-brachialis brevis; *cor.br.lg*, coraco-brachialis longus; *cp.st*, corpus sterni; *ext.cp.rd*, extensor carpi radialis; *ext. cp.ul*, extensor carpi ulnaris; *fl.cp.ul*, flexor carpi ulnaris; *gl.c*, glenoid cavity; *hu*, head of humerus; *hu'*, its distal end; *pct*, pectoralis; *pct'*, its cut edge; *pct''*, its insertion; *prn.br*, pronator brevis; *prn.lg*, pronator longus; *pr.ptgm*, pre-patagium; *pt.ptgm*, post-patagium; *sb.clv*, subclavius; *sb.clv'*, its tendon of insertion passing through the foramen triosseum, and dotted as it goes to the humerus; *tns.acc*, tensor accessorius; *tns.br*, tensor brevis; *tns.lg*, tensor longus; *tns.m.p*, tensor membranæ posterioris alæ. (After Parker and Haswell.)

plishes the down-stroke of the wing, which, of course, must be the most powerful in order to sustain the bird and accomplish the forward propulsion of the body. The up-stroke is provided for by the passage of a tendon from the small pectoral muscle, or subclavius, through a sort of pulley between the coracoid and scapula,

and to the upper side of the humerus. Associated with the movement of the wing is the arrangement of the feathers so that they form in the down-stroke a continuous sheet, practically impervious to the air, while on the up-stroke, owing to the flexibility of the feathers, the surface of resistance is much reduced.

The structure of the feather is somewhat complex. There is a long shaft, the basal part of which, the quill, is hollow. The vane

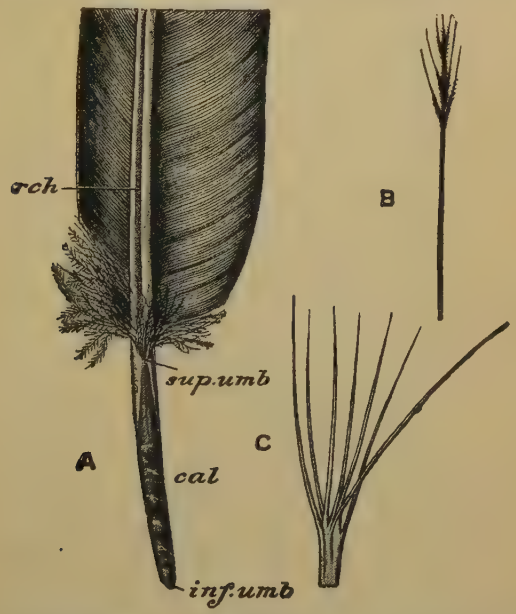


FIG. 245. — **Columba livia.** A, proximal portion of a remex. *cal*, calamus; *inf.umb*, inferior umbilicus; *rch*, rachis; *sup.umb*, superior umbilicus. B, filo-plume; C, nestling-down. (Parker and Haswell. C from Bronn's *Thierreich*.)

on each side of the shaft is composed of the barbs, and each barb sustains a series of barbules which are provided with minute barbicels. The latter terminate in minute hooks which interlace in the adjacent barbules so as to make a closely connected surface. The feathers are molted at regular intervals, but those of the

wings in most birds are lost in pairs at successive intervals, so that flight is not interfered with. In such birds as lose all the wing feathers at once, there is a period when flight is impossible. The molting of the feathers frequently changes the color of the bird, and this may also be accomplished by the flaking off of the terminal portions of individual feathers.

Many birds show a very striking habit of migration, making extensive trips in the spring and autumn. The migratory habit must be looked upon as gradually developed in certain species of birds, as there are many kinds which do not show any such instinct. Others migrate but short distances, while the more extreme forms travel thousands of miles, and make these extensive trips without any direct reference to the necessary food supply or climatic conditions. Just how the instinct is developed it is difficult to say, but several factors may have been active in establishing the habit. Local migrations to secure better food supplies may be considered as one starting point, while migrations for more suitable or better protected nesting grounds may be another factor. And these might both become adjusted to the variation in seasons, and once the habit is thoroughly established, we can understand how it may recur periodically and in the same kind of migration year after year. Certain species travel certain definite paths in these migrations, and it is believed that individual birds return year after year to the same locality, and that they may nest year after year in the same tree. The migration seems to have little relation to the size of the bird or other habits, as the strong fliers like the crow, the robin, the blue jay, and the woodpecker may remain in the same locality both summer and winter, while some of the feebler forms, such as the little warblers, make very extended migrations, going far north toward the arctic in summer, and to extreme southern points in the tropics for the winter. Certain species are known to travel the whole distance from Patagonia to Alaska every year.

The nesting habit of birds is another quite striking character, some species showing remarkable ability in the construction of their nests. Probably the most primitive form of nest is the sim-

ple resting place on the ground or on rocks, without any provision in the way of sticks or leaves or moss as a protecting structure, while such a place with the formation of a rim marks the beginning of the nest-building habit. Many species construct nests on the ground by weaving grass and leaves into a cup-shaped structure, within which the eggs are protected. Others fasten their nests in trees, building a compact structure of twigs, grass, etc., sometimes using feathers or wool as a lining. The oriole goes somewhat further and forms a hanging nest from the outer twigs of some limb, so that it is much better protected against the attacks of marauding enemies. Woodpeckers burrow into the trunks of trees, excavating a suitable cavity, and form their nests within.

Connected with the nesting habit is the period of incubation, which varies greatly in different species. In many forms the eggs hatch within a short time,—a week or ten days after deposition,—and the young birds are extremely helpless and must be cared for and fed by the adult birds. They grow very rapidly, however, and within a few days or a week may be able to leave the nest and take part in securing their food supply. This must be quite strenuous for the adult birds, for during the period of feeding in the nest they are obliged to secure an enormous quantity of food for the young, the robin, for instance, feeding the young birds about every five minutes throughout the day, each time supplying the birds with a caterpillar or portion of a good-sized earthworm. As there are three or four young in each brood, the number of worms carried is seen to be enormous. With other species the period of incubation is much longer,—three or four or even five weeks,—and the young birds, when hatched, are quite active, able to run about, and, to a large extent, to rely upon themselves to secure food. They are guarded, however, for some time by the adult birds, and with the quail, partridge, etc., the broods are usually kept together during the entire summer or perhaps on into the succeeding winter.

It is evident from the habits of birds that they have a very

important relation to human industries, some being of very great service on account of their feeding so extensively upon insects, most of which are injurious, and some forms on account of their high value as food. This is especially true of the game birds and those species which have been domesticated and are used both for the production of eggs and for their flesh. Of the domesticated species the common barnyard fowl is the most important, as it is used practically the world over and to a much greater extent than any other species. It is a native of Asia, and the original stock is still known in northern India, but differs very distinctly from our modern domestic birds. In fact, the domestic forms have been so much modified by selection and the formation of distinct races that some of them would seem to have no relationship whatever to the original form. The turkey, pigeon, ducks, geese, swans, and a few others have considerable importance as domestic species.

A Systematic Review of Birds

While the relationship of birds to reptiles is indicated in the development of the main structural characters, the group stands as a very independent one, and for the existing species the absence of teeth and presence of feathers and the modification of the fore legs are distinctive characters. Fossil forms included in orders now extinct were provided with teeth of the reptilian pattern, and showed various stages in the reduction of the tail from the long vertebrate structure to a short caudal bone supporting a broad expanse of feathers. Omitting these fossil forms, we have two principal subdivisions, one including those groups which are unable to fly and in which the wings are gradually reduced, with the absence of the keel on the sternum, and the legs more fully developed, so that they are running birds rather than flying; and the other group including those forms which are provided with a keeled sternum and which, in most cases, have well-developed wings, and whose locomotion is primarily by means of flight.

The first group, including the ostriches, cassowaries, emus, ap-

teryx, or kiwi, have the wings so poorly developed that they are unable to fly. The sternal keel is wanting, and this would suggest that these birds may have separated from the other species prior to the development of the keeled sternum, though it is possible that in the long period of wing inactivity the sternal keel has also been subjected to reduction. The most important species commercially is the ostrich, which, in South Africa, is the basis of a very large industry. Ostrich plumes from that country furnish the larger part of the world's supply. Ostrich farming is established, however, in southern California, and the conditions there seem to be favorable for its development. While used mainly for the plumes, the eggs are palatable, and any surplus above what is desired for rearing of birds can readily be utilized as food. Undoubtedly, among the arid sections of the Southwest ostrich farming could be carried on very successfully when the methods of handling these birds are understood.

FIG. 246. — Restoration of **Archeopteryx lithographica i. Meger** (Andriæ).

The birds of flight, which include the great majority of birds of the present time, have a very distinct keel upon the sternum, and, except for a few forms in which there is an extreme adaptation to aquatic life, they all are capable of flight. A hasty survey of the different orders and families must suffice, for the immense number of birds represented in all the countries of the world makes it impossible to cover the groups in any detail. As these birds are the ones which are native to our own country, and since the birds constitute one of the most attractive and, in fact, best-known

FIG. 247. — **Cassowary**. Photograph from mounted specimen in Ohio State University Museum. (Haskett photograph.)

groups of animals, every one should make it a point to become familiar with as many of the common species as possible. Every one who knows anything of birds at all is likely to know the robin, bluebird, blue jay, crow, and some other of the more common species, but in many cases, especially for such birds as sparrows, swallows, warblers, etc., there is no attempt to separate the distinct kinds. To familiarize one's self with the birds of his own neighborhood, one should begin by noting such forms as are familiar, and, fixing in mind any characters which may be observed, gradually extend the list to those birds which can be named at sight, until a considerable number are known. Forty or fifty species may be learned readily in the course of a few weeks, especially if one will give attention to the appearance of different kinds in the migrating season of spring.

FIG. 248. — Loon, **Gavia imber**. Photograph from specimens in Ohio State University Museum. (Haskett photograph.)

Order Pygopodes. — The diving birds have narrow bills and legs placed far back on the body. The feet are broadly webbed, and their habit is distinctly aquatic, some of the species being able to remain under water for almost incredible periods of time. The auks, grebes, and loons are familiar examples, but are seldom seen except in the vicinity of ponds or lakes. Many of the species are restricted to the arctic regions.

The penguins, which are even more extreme in their restriction to water, and which are unable to fly, are found in the antarctic regions or along the coasts of South America.

Order Anseres. — Ducks and geese constitute a large series, distinguished by broad bills, usually with distinct lamellæ, broadly

FIG. 249. — Wood duck, **Aix sponsa**. Photograph from mounted specimen in Ohio State University Museum. (Haskett photograph.)

webbed feet, and rather flat bodies. A few of these have been domesticated, and swans and geese and the domesticated duck, which is derived probably from the mallard or closely related form, have a considerable commercial value. Aside from their use as food, ducks and geese particularly are utilized largely for their feathers or down, and the feathers from the eider duck are sold under the name of eider down and have an extensive demand. The group includes a number of so-called game birds, ducks, geese, and brants being much sought for by sportsmen. At present, however, the hunting of these birds is under careful restrictions in nearly all of the states to prevent the unnecessary slaughter and extermination of the species. Since they are distinctly migratory, it becomes a matter of interest that regulations for their preservation should cover their breeding grounds and other places during the migratory periods.

Order Longipennes. — The gulls and terns form an extensive group of very graceful birds capable of long-sustained flight and for the most part occurring along shores of oceans or lakes, though some species, notably the albatross and petrel, occur at long distances from land.

Order Limicolæ. — This group includes what are commonly known as shore birds, because they abound along the shores of ponds, lakes, or streams, in search of worms and other animals, for which many probe into the mud and sand. They have a characteristic form, the bodies being slender and the legs very long and the beaks often long and cylindrical and admirably fitted for probing into the mud in search of food. Their feet are in some cases slightly webbed, but none of the species are adapted for swimming, to any extent, their habit being to wade near the shore and to restrict themselves to the mud flats or the shore lines of the ocean during low tide.

The group is a large one and includes the snipe, woodcock, plovers, curlews, turnstone, avocet, and a large group of sandpipers, in nearly all of which there is a close agreement in habit. They have also a wide range of migration, and are often found

over an extensive territory, both along fresh water and oceanic shore lines.

Many of the species are valuable game birds, the woodcock and snipe especially being highly prized as table delicacies. Their abundance, and the readiness with which they may be approached, makes them a rather easy prey for the sportsman, and during the hunting season their numbers are fearfully depleted by the reckless slaughter by thoughtless hunters. Much effort has been made to bring some restriction to bear upon this thoughtless destruction so that the species may not be completely exterminated.

Their worm-eating habits make them a ready means of transmission of various kinds of parasites, and their digestive canal is very frequently gorged with parasitic species, various kinds of tapeworms, etc., which find in this organ a convenient habitation. So far as is known, they do not serve as carriers for any parasitic species infesting man, and the parasitism which they suffer is important, therefore, only in so far as it affects the growth and condition of the birds which are killed for food.

Order Steganopodes. — In this group we have a quite characteristic structure in the beak, which is in most forms provided with a membranous sac suspended from the lower mandible, and forming a capacious pouch or pocket in which they may carry food. The feet are webbed, and the species are capable of swimming, although their more common habit is to wade near the shore line. Their food consists of fishes which they capture by diving, in which they are remarkably skillful. The pelicans are among the largest of the group; in fact, are among the larger of the whole group of birds and have a very large gular pouch. The white pelican is distributed over much of North America, while the brown pelican is restricted more to the tropical regions of the world. The cormorants have a smaller gular pouch and a more slender head and neck. Numerous species occur in different parts of the world, the common American form ranging throughout all latitudes. In China the cormorant is used as a means of capturing fish, the fisherman controlling them by means of a cord, and

slipping an ivory ring over the neck, so that the fishes which they capture may not be swallowed. An occasional fish is allowed to be eaten as an encouragement for their efforts in this method of fishing.

Orders Herodiones and Paludicolæ.—These are known as the wading birds, and have an extreme specialization in length of legs,

FIG. 250. — American Bittern, **Botaurus lentiginosus**, with nest and egg. Photograph from mounted specimen in Ohio State University Museum. (Haskett photograph.)

and in most cases also in length of beak. Many of the species are large, such forms as the stork, crane, heron, and flamingo being good examples. In former years the whooping crane and the sand-hill crane were very common throughout the United States, but in recent years their numbers have been much reduced and their occurrence is now quite rare. The blue heron is of rather

common occurrence, and its range covers a large portion of the eastern United States. It nests in swampy localities, sometimes immense numbers of them together, forming what are known as "heronries." The bittern, green heron, least bittern, and rails are also common and widely distributed species. The Old World stork ranges from northern Europe into the tropics. The white heron, or snowy egret, formerly a very common species, furnishes some most beautiful plumes, and the great demand for these in millinery has resulted in the almost complete extermination of the species. These plumes develop only during the breeding season, while the adult birds are rearing the young, and consequently the collection of the plumes means not only the destruction of the adult, but also the young, which are dependent upon the adults for food. Heroic efforts have been made during late years to prevent this destruction in order that the species may not be completely exterminated. It is feared, however, that so long as the demand for the plumes persists, the plume hunters will make every effort to secure all the plumes possible, in spite of any legal enactments to the contrary. The principal breeding places are now restricted to some of the more inaccessible parts of Florida, and the bird is rarely seen in any of the Northern States. Aside from this particular bird, the members of the group have very little commercial value. None of them are used for food, and their food, consisting largely of fishes, makes them rather inimical than beneficial from the human standpoint.

The flamingo is a quite remarkable species on account of the immense length of the legs and neck, and the peculiar modification of the bill, which fits it for feeding upon aquatic animals. Its nesting habit is quite remarkable, also, the nests being built up as domes of mud on the top of which, in a slight depression, the eggs are laid and the incubation performed.

Order Gallinæ. — The gallinaceous or scratching birds are a quite well-marked division, including a large number of conspicuous forms, such as pheasants, quail, ptarmigan, turkeys, and the common barnyard fowls. They are heavy-bodied birds adapted

for living on the ground. The wings are comparatively short and broad, and their flight, while often very rapid, is usually very short. Usually they remain permanently in one locality, or at least have very limited migrations compared with that of some other groups of birds. They are seed-eating or grain-eating birds, and have a large crop and strong gizzard. Most of the species nest on the

FIG. 251. — Prairie Hen, **Tympanucus americanus**. Photograph from mounted specimens in Ohio State University Museum. (Haskett photograph.)

ground, building rather loose nests of grass or herbage, and are concealed by adaptation in color to the surrounding vegetation. The nest may include a large number of eggs, such species as the quail, prairie hen, and others incubating as many as thirteen to fifteen in a nest. The period of incubation is usually long, and the young, when hatched, are capable of running about and securing food for themselves. They remain, however, in flocks or coveys for a considerable time under the care and protection of the

adult birds. All of the species show protective resemblance, the ptarmigan in arctic regions showing white plumage, and the quail, prairie hen, etc., being mottled or marked so as to blend in with the vegetation in which they commonly occur. Practically all of the species are valuable for food, and many of them, such as the prairie hen, quail, partridge, pheasant, etc., are conspicuous game birds, in some countries being preserved under careful restrictions in order to avoid their extinction. The common barnyard fowl, the most important from the standpoint of domesticated forms, is now distributed throughout the world, and is the basis for the most important industry associated with bird life. The turkey, derived originally from the early wild species occurring in America, has taken rank as an important domesticated species, but is largely exterminated as a wild bird, except in some of the remote and unsettled districts of the country. The quail, prairie hen, and partridge are difficult to keep in confinement and appear to resist all efforts at domestication. The guinea hen, peacock, golden pheasant, and Mongolian pheasant, which have been introduced into America from the Old World, are, as yet, much less important as domesticated species.

Order Columbæ. — The doves and pigeons resemble in some respects the previous order, being grain-eating birds with a complex alimentary canal, but they have long wings, and their powers of flight in many species are very great. A quite distinct character is found in the presence of a soft, fleshy structure at the base of the beak over the nostrils. The domestic pigeon derived from the wild rock pigeon of Europe is kept quite extensively as a source of profit, and the rearing of squabs is in many places a quite extensive industry. The wild pigeon, formerly a most conspicuous bird in the United States, is practically unknown throughout the Mississippi Valley, the reason for its disappearance being unknown. The common turtle dove, or morning dove, is at present the best-known wild species of this region. Related to the pigeons was the peculiar dodo, which occurred in some of the islands of the Indian Ocean, and became extinct during the latter part

of the seventeenth century. It was a large bird and extensively used for food, and its extinction resulted from its slaughter for this purpose without any attention to modes of preservation.

Order Raptores. — The birds of prey are well-known forms. The hawks, eagles, and owls have very distinctive characters, and many of the species are so common as to attract attention. They are provided with a curved beak fitted for capturing and tearing prey. The claws are long and sharp, the alimentary canal is simple, without a distinct crop or gizzard, and they may be recognized from the external character of the beak, this being covered at the base with a membrane called the **cere**. The hawks and eagles are diurnal in habit, usually nesting in high trees and sometimes on cliffs or rocks away from human habitations, and their food consists of different kinds of animals, the eagles capturing fish as well as smaller mammals or birds, while the hawks, for the most part, feed upon small mammals. On the whole, these birds must be considered as beneficial, as the attacks on poultry are due to a very few species, and are too infrequent to offset the immense numbers of injurious animals which they destroy. The owls, which are distinctly nocturnal in habit and which have the eyes directed forward, are likewise, as a rule, distinctly beneficial, and should be preserved rather than destroyed. In most states where any restrictions are placed upon the killing of birds, the hawks and owls are among those which are protected, and where this is not the case, it would be much better if legal enactments, as well as public sentiment, should be directed to their protection. We have included here, also, certain scavenger birds, such as the turkey buzzard, carrion crow, condors, and vultures, which feed mainly upon the carcasses of dead animals, and which in some localities are very important in the service which they render. This is especially true in certain tropical regions, and in many cities of Central America the carrion crows are very carefully protected by law, as they are about the only sanitary force which is maintained. The condors of the Andean region are notable on account of the

immense height at which they fly, and the fact that their soaring flight at this height is apparently performed without the slightest

FIG. 252. — Snowy owl, **Nyctæa nyctæa**. Photograph from mounted specimens in Ohio State University Museum. (Haskett photograph.)

movement of the wings, a fact which has been a perennial puzzle to naturalists.

Order Psittaci. — The parrots and parakeets are distinguished by having extremely thick, short beaks, the upper mandible being very much curved and extending over the lower one. The feet are modified so that two toes are directed backward and two forward. The birds of this order are represented by a great number of species throughout tropical America and also in Asia and Africa. Some of the species are notable as curiosities, and form for this purpose a considerable commerce. The Carolina parakeet, formerly occurring as far north as southern Iowa, Ohio, and Virginia, is now much reduced in numbers and is known only in small numbers in the more southern part of the United States.

Order Pici. — The woodpeckers agree with the preceding order in having two toes directed backward, the inner one being revolved, and in this group the structure is particularly serviceable in connection with their habit of clinging to the bark of trees. Some of the tail feathers are usually sharply pointed, and assist in supporting the body against the surface of the trees. While capable of perching on the branches or twigs, they are most frequently seen running up and down the trunks or around the larger limbs. They do this in search of insects, not only capturing those on the surface, but boring into the bark and wood in order to secure the grubs or wood-boring species. Their bills are large and very strong, enabling them to penetrate hard wood, and they form their nests within the branches of trees or sometimes in holes, often taking advantage of soft or hollow wood. The tongue is also specialized and capable of being greatly protruded, and is distinctly barbed at the tip. Its base is associated with two extended flexible portions of the hyoid bone which pass back and up to the top of the skull, so that there is a much longer base of attachment for the muscles. Most of our species are distinctly serviceable in the capture of insects, and they constitute one of the most important checks for the destructive insects in forests,

and should be most carefully protected. One species, the little sapsucker, punctures the bark of trees and feeds upon the sap, and the numerous punctures often cause serious wounds and are a disfigurement to the trees that are attacked.

Order Passeres. — This group includes the larger number of the birds, and for our own fauna a vast majority of the familiar species, such as sparrows, warblers, swallows, thrushes, blackbirds, etc. They are known as perching birds, the general habit being to live in trees, and their feet are well adapted for clinging to twigs and small branches. The beak differs somewhat in form and size, and is usually somewhat conical, the two mandibles being of nearly equal size. The toes are arranged three in front and one behind, provided with sharp claws. The tarsus is usually naked. It will be possible here to mention only a few of the more typical representatives with a very brief indication of their habits. The crows and jays are among the lower members of the group, and are characterized by a harsh voice, and crows are sometimes troublesome in their attacks upon newly planted corn, but on the whole they are not especially destructive. They usually gather in large flocks for some definite roosting place at night, and these are termed "rookeries." The blue jay is an active, loud-voiced species that is commonly known. The group of blackbirds and orioles includes a number of familiar and handsome species, the oriole in particular being interesting in the form of nest which it builds, while the cowbird has the peculiar habit of laying its eggs in the nests of other birds, which are forced to rear its young. The sparrows include one of the largest groups both here and in other countries, the striking character being a thick, heavy bill. The common canary, goldfinch, English sparrow, song sparrow, chippy, etc., are included in the group. The English sparrow, introduced from Europe about the year 1850, has spread over the country and taken possession of all suitable locations, in many instances crowding out birds which depend upon similar conditions. Its introduction must be looked upon as a misfortune, as its service by no means counterbalances the

annoyance which it occasions. The warblers are small birds, and there are a great number of different species. They are extremely active little creatures, most of them best known in the United States during their migrations northward in spring and southward in autumn. A few nest in this latitude, especially the yellow warbler. The flycatchers include the kingbird, pewee, phœbe, and a number of others, and they are very active and catch insects on the wing, being distinctly serviceable in this manner. The wrens are also active insect-catching birds, the little house wren being most desirable in any dooryard. The swallows and martins are noted for their graceful flight, and their habits in catching insects render them serviceable, while their nests in the eaves of barns, in cliffs, or mud banks show an admirable adaptation in architecture. Other forms of special interest are the creepers seen running over the trunks of trees. The tanagers of bright scarlet color, and the vireos, some of which are most remarkable species, and the bluebirds are most familiar in spring. The thrushes, catbird, and mocking bird are especially noted for their songs, these being perhaps the most highly specialized songsters of the whole class. The common robin is so abundant and familiar that it must be known by almost every one who has any acquaintance with birds at all. This is but the merest glimpse at the long array of most attractive species, and for further acquaintance with them, the student should consult Coues' *North American Birds*, or Chapman's *Birds of Eastern North America;* besides these there are a number of other valuable works which contain a great amount of information regarding their life and habits.

Economic Importance

Several important industries are connected with the birds, including both wild and domesticated forms. Of these the production of food in the form of meat and eggs is one of the most important. Doubtless, if the common hen is taken into account, this is by far the most important of all, but these industries

assume many different phases, running from complete control, as in the breeding of chickens and production of eggs in the most perfectly domesticated forms, to the hunting as game of species which are sought as delicacies for the tables of epicures.

Eggs of wild birds are used not only as a food supply but for the formation of collections, and in this direction all have a distinct market value varying from a few cents for the more common species to many dollars for some of the rarities, and to thousands of dollars for such extreme rarities as the egg of the extinct great auk, of which there are but a few specimens known. The collection of eggs as a basis for the scientific study of birds and their preservation in scientific collections is, of course, fully justified, but indiscriminate collecting, without any purpose but to assemble as many different kinds as possible without any reference to the scientific data which should make them valuable, has been very largely replaced by the use of the camera in securing photographs of the nests and eggs and the natural surroundings in which they may be found. This form of bird study, which may be carried on without any destruction of the birds, results in permanent records, which may be found to be of distinct scientific value as well as a source of great pleasure. Similarly, it may be said that the collection of bird skins to mount birds, so far as they are needed in scientific study, is fully justified, but the slaughter of birds for the mere gathering of collections which will never be put to a useful purpose should be discouraged.

Another form of industry is based upon the feathers of birds, and involves many different kinds. Those of domestic species, such as the hen, turkey, duck, goose, swan, etc., are used extensively for the filling of pillows, cushions, mattresses, and to some extent in upholstery, but their use is being replaced to some extent by other materials. Feathers are also used in the manufacture of garments, muffs, boas, and other articles of dress, in some instances being the result of much labor and expense. The extreme, perhaps, is represented in the fine capes manufactured by the natives of the Hawaiian Islands, the feathers being collected

from a single species of bird which bears but two feathers of the kind used, so that the value of a cape, measured in the labor involved in its manufacture, involves thousands of dollars. One of these capes deposited in the Smithsonian Institution is said to be worth fifty thousand dollars. Feathers as ornaments have been used probably from very primitive times; certainly they constituted a large part of the decorative outfit of the different tribes of North American Indians. In later society, however, they assume a principal part in the form of millinery, many millions of birds being used in this industry. The fashion of using entire birds as decorations upon hats, while perhaps somewhat less in vogue than a decade or more ago is still a very common practice, and this use results in the destruction of an enormous number of birds, some of them quite rare and in danger of extinction. That feathers constitute a most beautiful form of decoration will not perhaps be denied by any one, but discrimination in the use of feathers which may be secured without destruction of the birds or the starvation of the young, and the discarding of all use of entire birds, would mean a great reform in this respect. Ostrich plumes and the more brilliant feathers of many kinds of birds may be used without such wanton destruction as is necessary for the procuring of some of the kinds that have been largely used in millinery. While the protection of birds from this source of extinction may be waged purely as a sentiment based on the desire to preserve these creatures that have so much of beauty in their color and song, it is also of enormous importance because of the function which birds perform in the control of insect enemies to crops and forests.

CHAPTER XX

CLASS MAMMALIA

The mammals, which are commonly considered the highest group of animals, inasmuch as the human species is included in it, shows its distinct character in the body covering of hair, in the viviparous reproduction which is common to all but the most primitive members of the group, and perhaps most decisively in the method of nutrition, the young being nourished by a secretion of milk from special glands, the mammary glands. This mode of nourishment is true of all the members of the group, even those in which the young are developed in eggs which resemble the eggs of reptiles or birds. Along with these more fundamental characters are others which are less universal in occurrence but which ordinarily distinguish the group, as, for instance, the development of four limbs for locomotion, the presence of teeth in the jaws, and the differentiation of distinct regions of the vertebral column. Some quite striking departures appear, as the modification of the fore limbs into wings for bats, into flippers for seals, and arms for primates. Also distinct specializations in the hand and foot and in the varying number of fingers and toes, reduced, in the most extreme form, to a single toe as in the horse.

The mammals have a highly specialized dentition, the teeth in all higher groups being differentiated and adapted to different work. The general types are **incisors**, **canines**, **premolars**, and **molars**. The first are usually sharp and fitted for cutting, the second often fang-like and especially developed in the carnivorous animals, the others more or less modified as grinding structures.

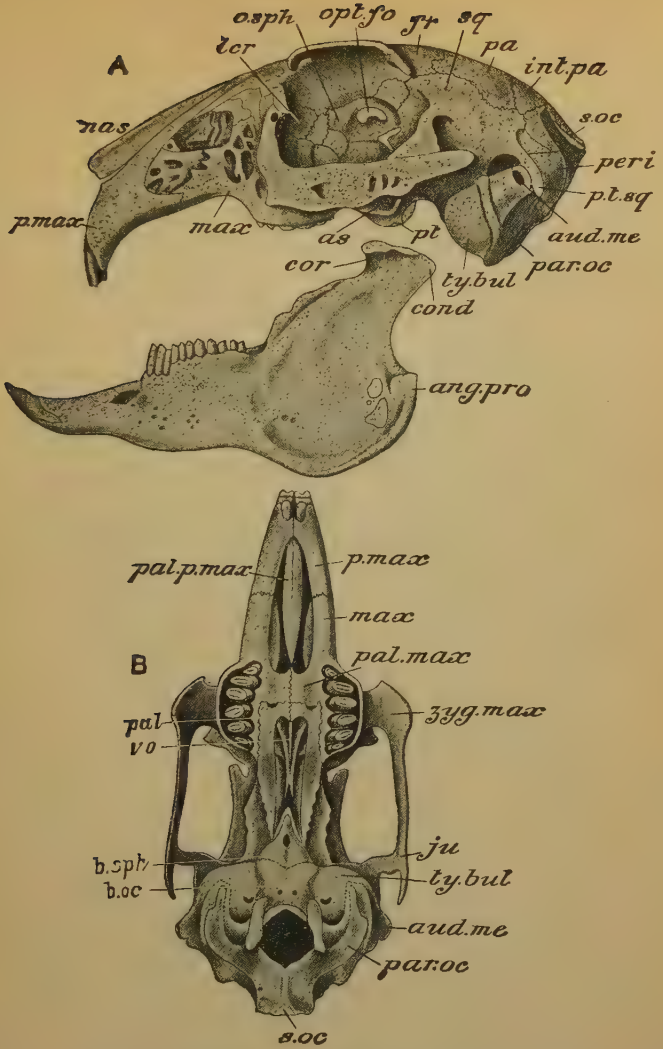


FIG. 253. — **Lepus cuniculus**. Skull of rabbit. A, lateral, B, ventral, view. *ang.proc*, angular process of mandible; *as*, ali-sphenoid (external pterygoid process); *b.oc*, basi-occipital; *b.sph*, basi-sphenoid; *cond*, condyle; *fr*, frontal; *int.pa*, interparietal; *ju*, jugal; *lcr*, lachrymal; *max*, maxilla; *nas*, nasal; *opt.fo*, optic foramen; *o.sph*, orbito-sphenoid; *pa*, parietal; *pal*, palatine; *pal.max*, palatine plate of maxilla; *par.oc*, paroccipital process; *pal.p.max*, palatine process of premaxilla; *p.max*, premaxilla; *per*, periotic; *pt*, pterygoid; *p.t.sq*, post-tympanic process of squamosal; *s.oc*, supraoccipital; *sq*, squamosal; *ty.bul*, tympanic bulla; *vo*, vomer; *zyg. max*, zygomatic process of maxilla. (After Parker and Haswell.)

The stomach in the ruminants is quite specialized, containing four compartments and adapted to the method of taking food. The aortic arch turns to the left, instead of to the right as in birds, showing the persistence of left instead of right arch of reptiles. The cerebrum is large and in most of the groups much convoluted. The eye is well developed, though not more specialized than in

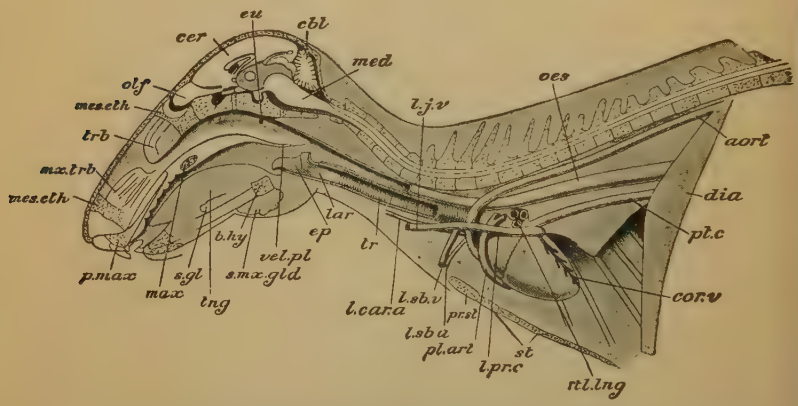


FIG. 254. — **Lepus cuniculus**. Lateral dissection of the head, neck, and thorax. The head and spinal column are represented in mesial vertical section; the left lung is removed; the greater part of the nasal septum is removed so as to show the right nasal cavity with its turbinals. *aort*, dorsal aorta; *b.hy*, basi-hyal; *cbl*, cerebellum; *cer*, cerebral hemispheres; *cor.v*, coronary vein; *dia*, diaphragm; *ep*, epiglottis; *eu*, opening of Eustachian tube into pharynx; *lar*, larynx; *l.j.v*, left jugular vein; *l.sb.a*, left subclavian artery; *l.sb.v*, left subclavian vein; *med*, medulla; *mes.eth*, mesethmoid; *mx.trb*, maxilla-turbinal; *œs*, esophagus; *olf*, olfactory lobe; *pl.a*, pulmonary artery; *p.max*, premaxilla; *pr.st*, presternum; *pt.c*, postcaval vein; *rt.lng*, root of left lung with bronchus and pulmonary veins and artery cut across; *s.gl*, sublingual salivary gland; *s.mx.gld*, submaxillary salivary gland; *st*, sternebræ; *tng*, tongue; *tr*, trachea; *trb*, ethmoturbinals; *vel.pl*, soft palate. (After Parker and Haswell.)

birds, but the ear shows a decided advance in the greater length of the cochlea. The external reproductive organs are more specialized than in the preceding group, and much more care is accorded to the young.

Mammals have a wide distribution over the earth and are capable

of extended migrations, being surpassed in this feature only by the birds, while in adaptation to extremes of climate they show every possible range, from tropical to arctic conditions. They are also adapted to a great variety of situations, and while the majority are terrestrial, such aquatic forms as the seals, sea cows, and especially the whale, illustrate the possibility of extreme aquatic habit. The group is divided primarily on the basis of the methods of reproduction, the more primitive forms being oviparous, and these followed by non-placental forms, and these again by

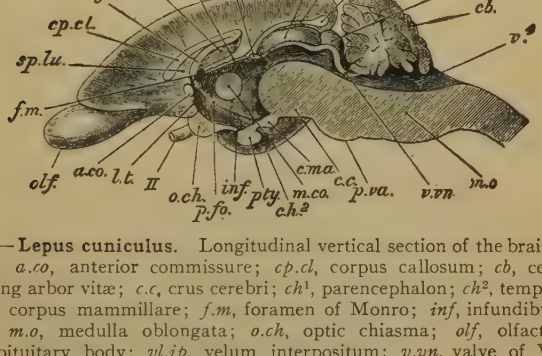


FIG. 255. — **Lepus cuniculus.** Longitudinal vertical section of the brain (natural size). *a.co*, anterior commissure; *cp.cl*, corpus callosum; *cb*, cerebellum, showing arbor vitæ; *c.c*, crus cerebri; *ch*¹, parencephalon; *ch*², temporal lobe; *c.ma*, corpus mammillare; *f.m*, foramen of Monro; *inf*, infundibulum; *ly*, lyra; *m.o*, medulla oblongata; *o.ch*, optic chiasma; *olf*, olfactory lobe; *pty*, pituitary body; *vl.ip*, velum interpositum; *v.vn*, valve of Vieussens, *II*, optic nerve. (From Parker's *Zoötomy*.)

placental mammals which show the viviparous method of reproduction in the most specialized form. Considering these groups separately we have: —

SUBCLASS MONOTREMATA

The monotremes come close to reptilian animals both in method of reproduction and in character of the skeleton. The group is represented by the duck-billed platypus and spiny ant-eaters of Australia and New Zealand, but must have had a much greater

number of forms and wider range in previous time. No doubt they stand at present as somewhat specialized offshoots from the more primitive and reptilian-like ancestors, and illustrate the long survival of the primitive mammalian forms. Their habits are subterranean, their burrows being formed in the banks of ponds or streams, and within these burrows they form nests in which the eggs are deposited and the young reared. The eggs are nearly globular, about one third of an inch in diameter, and closely resemble the eggs of some reptiles. Their period of incubation is uncertain, probably lasting some weeks, and the newly hatched young are dependent upon the milk secretion from the adult for nourishment. There is no permanent marsupial pouch, but the young are held closely to the ventral surface of the body, and secure milk from mammary glands which open exteriorly by a number of pores, there being no nipple such as is developed in the higher groups of mammals. The duck-billed platypus has a broad, duck-like beak with no teeth, is somewhat larger than a muskrat, and its habits are comparable to those of the beaver, although it is by no means so intelligent in its operations. The ant-eaters have much narrower beaks and thicker, shorter

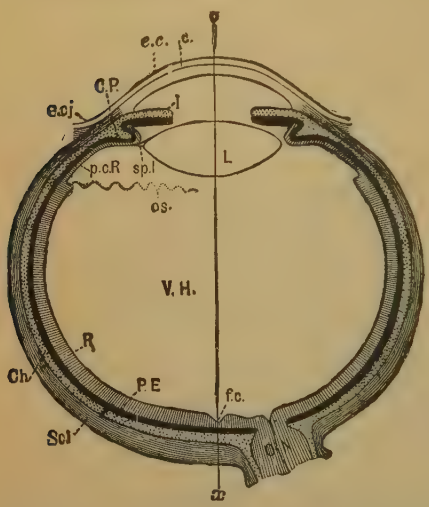


FIG. 256. — Diagrammatic horizontal section of the eye of man. *c*, cornea; *ch*, choroid (dotted); *C. P*, ciliary processes; *e. c*, epithelium of cornea; *e. cj*, conjunctiva; *f. c*, yellow spot; *I*, iris; *L*, lens; *ON*, optic nerve; *OS*, ora serrata; *o–x*, optic axis; *p. c. R*, anterior non-visual portion of retina; *P. E*, pigmented epithelium (black); *R*, retina; *sp. l*, suspensory ligament; *Scl*, sclerotic; *V. H*, vitreous body. (From Foster and Shore's *Physiology*.)

bodies, one species, the spiny ant-eater, being provided with quills, or spines similar to those of the porcupine, while the other species,

FIG. 257. — Duckbill, **Ornithorhynchus anatinus**. (After Vogt and Specht.)

FIG. 258. — Spiny ant-eater, **Echidna aculeata**. (After Vogt and Specht.)

the silky-haired ant-eater, has a slightly less spine-like body covering. In both forms the hair is quite long and coarse, while in the duck-bill it is very fine and short. No particular economic

importance can be assigned to these peculiar creatures, but they are of special interest in showing the intermediate forms of evolution between the reptilian and the mammalian groups.

Subclass Marsupialia

The marsupials stand midway between the monotremes and the placental mammals. The young are produced viviparously and at a very immature stage, there having been no placental attachment to the oviducts of the female. They are protected in pouches of the ventral wall of the body within which the mammary glands are located, and for some time after birth they are permanently attached to these glands. In structure the marsupials differ from the other mammals in that the oviducts open separately instead of joining to form a uterus. The group includes a wide range of species adapted to very diverse modes of life, and represented in Australia by forms which parallel the higher mammals occurring in most parts of the world at present. The group is restricted mainly to the Australian region, but one common species, the opossum, occurs in North America, while a number of smaller forms, the pocket mice, are found in Central and South America. The native mammalian fauna of the Australian region is almost entirely composed of marsupials, and is considered as being much more primitive in character than in other portions of the earth. There are found rat-like forms which might be compared with our rodents, dog-like and fox-like forms, the monkey-bear, and native wolf, which are similar to our carnivorous species. There is a flying species resembling remarkably our flying squirrel, and the kangaroos may be associated or compared with our rabbits, the fore legs having been much more reduced in size and the hind much more perfected for jumping than in our rabbit or hare.

The opossum is not an unimportant species in our fauna, since it is largely used for food throughout the territory where it occurs, and it is a fairly common object in the markets of the larger cities to the north of its natural range. They occur in timber or thickets,

and notwithstanding the many animals which prey upon them, they seem quite able to maintain their numbers. They produce eight or ten at each litter and probably several litters each year. No attempt has been made toward domesticating this species, but it survives fairly well in confinement, and could very likely be adapted to domestication in the course of time. In the Australian region the kangaroos are of considerable importance

FIG. 259. — Virginian Opossum, **Didelphys virginiana**. (After Vogt and Specht.)

because of their destruction of vegetation, but the majority of the marsupial forms have comparatively little importance.

SUBCLASS MONODELPHIA OR PLACENTALIA

This division, which includes all of the remaining forms of mammals, is distinguished by the development of an attachment between the embryo and uterine walls of the adult, the **placenta**, and in this respect is distinctly in advance of all of the preceding mammals. It embraces a large number of groups, and contains practically all of the dominant mammalian animals of the present

time. The oviducts combine to form a double or single uterus and single vagina, which has an independent external opening, not being combined with the alimentary tract. The group includes a number of quite distinct orders which may be considered separately, and some of these types will be considered more in detail as representatives of the group at large.

Order Edentata. — The edentates, first established to include mammals in which the teeth are wanting, now embrace a number of groups in which teeth are present. The species differ in a number of respects from the other groups of mammals, and it

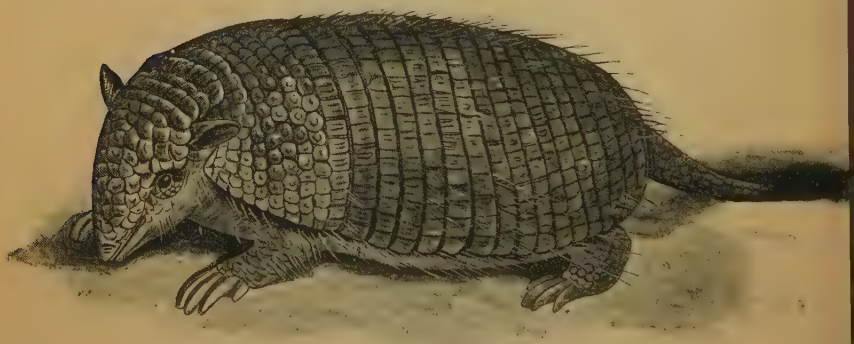


FIG. 260. — Tatu armadillo, **Dasypus sexcinctus.** (After Vogt and Specht.)

has been suggested that they may have had an origin independent from the other placentals. While possessing all the essential developmental characteristics, they have very little in common with the more conspicuous groups, and must at least be considered as early separated from the placental stock. The group is found largely in tropical regions and is represented particularly in South America, although some species occur as far north as Mexico. Some of the species have distinct hairy covering, but in other cases the surface of the body is protected almost entirely by horny plates, or shields, these being especially marked in the pangolin, which

has a large number of overlapping scales, and in the armadillo, which has numerous bony plates, some of these closely united, and forming a very perfect shield for the upper parts of the body. Some species, by doubling the body, can form a most perfect ball, the entire outer surface of which is protected by the bony plates. The aard vark, the South African species, and the pangolins of Southern Asia, represent the group in the Old World, while the ant-eaters, sloth, and armadillos are the American representatives, the latter occurring as far north as southern Texas. The species occur over a very large region of the American continent, and in early geological time some of them were animals of great size. The megalonyx, glyptodon, and megatherium are among the most striking of these extinct species.

Order Rodentia. — This is an extensive group of mammals, including for the most part small species that appear to be inferior to the larger members of the group. They present, however, a very strong specialization in the development of the incisor teeth, which are very large and strong, usually chisel-shaped and fitted for gnawing wood or hard substances and with a constant growth during life so that the wear is constantly replaced. They have toes usually five in number, and a tail of varying length, being composed of but few vertebræ and very short in rabbits, and long in some of the squirrels, rats, etc., and much broadened and flattened in the beaver. On account of their ability to gnaw wood and the fact that they feed largely on grain or the bark of shrubs and trees, they are among the species which are of great economic importance. A few are valuable on account of their use as food or for their fur.

The group including the rabbits is one of wide distribution, and includes species of moderate size, varying from the larger hares or the jack rabbits down to the little cottontail. They are characterized particularly by the large ears, the fact that there are four incisors in the lower jaw, the outer ones very minute, a short tufted tail, the disparity of fore and hind legs, the latter being large and strong. The common wood rabbit, the cotton-

tail, is distributed quite universally over the United States and is sometimes a very serious pest on account of its attacks on trees and shrubs, stripping the bark and thus killing the plants (see Fig. 261). It feeds on a variety of vegetation, selecting the most succulent plants of all kinds, and the extent of its injury will depend on the kind of plants which are attacked. It is also used quite

FIG. 261. — Apple tree killed by rabbits. (From Lantz, Bull. Biol. Sur., U. S. Dep. Ag.)

extensively as an article of food, so that it may be either destructive or useful. The northern hare and prairie hare are considerably larger, their distribution is more northern, and they change from gray to pure white for the winter season. The jack rabbits of the plains region are large, and very swift runners, and in some localities

become a most serious pest on account of their destruction of crops. In some instances they are rounded up and killed in immense numbers in order to free the localities from their depredations. The European hare introduced into Australia has become a most serious pest, and the Australian people have had great difficulty in keeping it in control.

The family including rats and mice (Muridæ) is one of the most destructive groups with which we have to contend. They are distributed generally over the whole world, and some of these species have become distinctly cosmopolitan. All of them are small, the largest being our common muskrat, while some forms are found even smaller than the common house mouse. The hair is rather short and the tail is scantily furred, or naked and scaly. The species, except the muskrat, may all be considered destructive. The muskrat is distinctly aquatic in habit, constructing dome-like houses in shallow water; and within these houses it spends the winter, or where the conditions are favorable it lives in banks of streams or ponds. It has some value on account of its fur, which is quite commonly used, and it is trapped for this purpose, and in addition it is used in some localities as an article of food. Its flesh is probably fully as palatable as that of the rabbit, and when skinned it is very likely sold under this name. Where swampy areas give it suitable conditions, it might very properly be considered as a species worthy of protection or cultivation.

Of the rats and mice the common house mouse is perhaps the most universally distributed throughout the entire world, occurring in almost every dwelling and building that offers it the least opportunity. While originally an Old World species, it is now distributed throughout the entire civilized world, where it is limited to the habitations of man, having adapted itself very perfectly to these associations. Its power of destruction is very great, and the contents of stores, warehouses, barns, granaries, corn cribs, etc., pay it a very heavy tribute. Not only is the vast amount of stock eaten a damage, but in many cases its gnawing through places and into receptacles of various kinds results in

serious damage. It is very possible also that in its migrations from house to house and visitations to food supplies in different quarters it may distribute germs of disease. The house rat, like the mouse, is an Old World species, or rather there are two species under this name, the black rat and the brown rat, or Norway rat. The former was introduced into America in early days and was, until somewhat recently, the common abundant species, but it is now largely replaced by the brown rat, which is slightly larger and lighter in color, and except on close examination might not be recognized as different. Losses from rats have been estimated recently to be something like fifteen millions of dollars a year in the United States, this being mainly in the destruction of grain and other food products, upon which they commonly live. They are found in dwellings, barns, granaries, mills, around wharves, and also in great numbers in the holds of ships. While their damage is fully appreciated, and much effort has been made to exterminate them, they have been able to survive and usually to multiply in such numbers as to retain their destructive position. Aside from the somewhat numerous losses caused by their attacks on food materials, they have come into much prominence lately on account of their relation to the spread of the bubonic plague. While only indirectly responsible for carrying this disease, they are nevertheless a menace in this direction, and their extermination is an important factor in providing a prevention for the disease. Both rats and mice may be destroyed by means of bisulphide of carbon or hydrocyanic acid gas, and in buildings which can be thoroughly closed and vacated for a time or in which certain portions infested by the vermin can be so treated, this is the most effective method of control. Cats and rat terriers, ferrets, and to some extent skunks and weasels, assist in their destruction, but all of these agencies have not proven equal to the task of thoroughly subduing the pest.

Related to the rats and mice which have adapted themselves to human habitations, we have a number of species which occur commonly out of doors and which are the cause of great losses

to farm products, orchards, nurseries, gardens, etc. These pass under the common name of meadow mice, field mice, voles, etc., the more common ones in the United States belonging to the genus *Microtus*. This genus includes several species which are similar in habit, all of them living at or near the surface of the ground and feeding upon the bark of trees, roots of plants, and grain when available. The larger species are about five inches in length and the smaller ones only about four inches long. They are not commonly observed, since they live under the vegetation

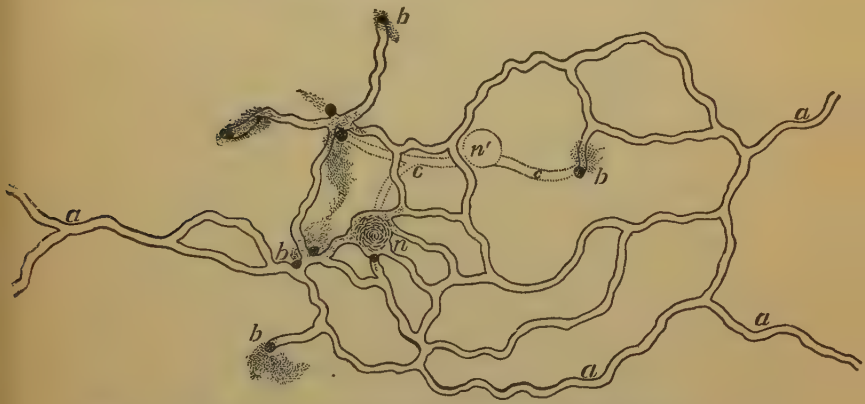


FIG. 262. — Nests, burrows, and trails of **Microtus pennsylvanicus**. *a*, surface trails; *b*, opening to burrows; *c*, underground tunnels; *n*, surface nest; *n'*, underground nest. (From Lantz, Bull. Biol. Sur., U. S., Dep. Ag.)

or decayed leaves and rubbish at the surface of the ground, and make numerous runways which can be noticed easily if the loose material at the surface of the ground be raked away. These trails form intricate affairs and connect with openings which pass into burrows that extend slightly below the surface of the ground. Such a series of runways is shown in the accompanying figure taken from a government publication on this species. The food consists of stems and blades of grass, leaves of plants, unripe seeds, grain, bark of orchard trees, various bulbs, roots, and

occasionally such animal food as snails, and in fact almost all sorts of nutritious material which may be available in their localities. Food is stored in some quantity, and doubtless for the sake of winter supply, but the species in this country are quite active during winter and probably do not indulge in any winter sleep. Their activity through the winter is apparent in the spring when the snow melts away, showing great numbers of trails which have been formed beneath the snow in their wanderings in the vicinity of their nests While the loss of grain, grasses, and vegetation is great, a most conspicuous damage occurs in the girdling of orchard trees. Apple, pear, and other fruit trees are sometimes killed in large numbers by the mice. While this is similar to the girdling caused by rabbits, it may be distinguished from the work of those rodents by the minute teeth marks, and the girdling is somewhat more smoothly done and usually closer to the ground. Loss from the work of these pests is estimated at something like eight million dollars annually. While somewhat difficult to control, there are a number of courses which may be taken advantage of to reduce their numbers. Cold winters, especially if the snow is scant, and long, dry periods in summer are very unfavorable, and severe frosts following heavy rains are said also to destroy great numbers of them. In some cases epidemic diseases break out and destroy immense numbers. Natural enemies are numerous, and those which should be most appreciated are carnivorous birds and mammals. Most of the species of hawks and owls feed upon these forms of rodents and are among the most efficient checks upon their increase. These should be encouraged in every way possible. Many mammals, such as skunks, weasels, and shrews, are perhaps most serviceable as covering the larger territory in which the mice are troublesome. Wolves, lynxes, badgers, raccoons, and opossums are said also to feed upon them, and while not desirable in too close proximity, are worthy of encouragement in their attacks on these destructive animals. Both field mice and house mice and rats are utilized as food by these forms. Weasels are especially important in this connection, particularly

in the more settled portions of the country where the larger carnivorous animals are wanting. Cats and dogs, of course, may

FIG. 263. - Apple tree injured by meadow mice. (From Lantz, Bull. Biol. Sur., U. S. Dep. Ag.)

be very efficient also, and can be utilized to good advantage in localities where the field mice are abundant. Snakes are quite efficient in destroying these pests also, especially the larger species, such

as the bull snake, black snake, and rattlesnakes, but the latter, of course, are not to be encouraged, since they are too dangerous. Field mice may be caught in great numbers by the use of traps and may be killed by poisons, but the latter must of course be used with great caution, since it is so likely to be secured by other animals. Of the traps available, the little cyclone traps are especially efficient, and, if scattered in places where the mice are plentiful, will serve a good purpose. The burrows may be treated with fumes of bisulphide of carbon and the nests cleared out by this means.

The white-footed mice or deer mice are very interesting little creatures, but, like other members of the family, quite destructive in their attacks upon vegetation, grain, etc. They differ from the other mice mainly in the white color of the under side of the body and the long tails and large ears. They occur as outdoor species, but are very likely to enter isolated houses, and at times prove very destructive by gnawing through wood and cutting up clothing for the formation of nests.

The beaver is one of the most interesting of rodents, and the largest and heaviest of the species occurring in the northern regions. It is aquatic in habit, living in burrows in the banks of streams or ponds, and in some cases builds very extensive dams in order to secure a constant level of water for the protection of its burrows. The opening of the burrow is under the water and is entered always from under water, there being usually no outlet above ground, although the nest is frequently located within a foot or two of the surface, and there is doubtless some ventilation secured through the soil. In cutting trees for the construction of dams, or to secure the bark as food, the beaver cuts deep gashes into the tree on all sides, gradually approaching the center, and the tree necessarily falls in the direction of its principal weight. The beaver has no control over this direction, except as it may select trees which may be leaning toward the water edge. The engineering skill displayed in the construction of the dams is sometimes apparently very great, but must be considered as the

result of special adaptation and instinct rather than as due to the intelligent operation of any individual animal. The nest may include a number of individuals, and there is some approach to community life, especially in groups of animals which may take up a favorable site to work in union in building dams and for protection of burrows. Formerly the beaver was of great commercial importance, as its fur is of very fine quality, but the constant trapping has resulted in practically exterminating the species from the greater part of its range. It still occurs in the more remote portions of Canada and a few of the less settled states. Its European representative is similar in habits, and occurs throughout the wilder portions of northern Europe. If properly protected by regulations guarding the younger individuals, it would seem entirely possible to preserve this species and to grow it in such numbers in suitable swamp areas as to make it a profitable commercial species.

The group of squirrels includes a number of quite small species and a wide range of habit, some burrowing in the ground, others living in the cracks of rocks and fences, and still others nesting in trees and showing a very distinct arboreal habit. The ears are prominent, the tail in some forms is short, with scant hair, and in others large, very long, and with long hair, so as to form a very prominent brush. The spermophiles live in burrows in the ground, have short tails and small pouches in the cheeks. They seldom if ever attempt to climb trees, and during the winter are dormant for perhaps the most of the time. Little if any food is stored up for winter use. They are most common in meadows, and their economic status is somewhat uncertain, as they feed in considerable part upon insects and may be of distinct service in reducing the numbers of destructive species, but on the other hand, they feed in some part on vegetation, and are especially credited with digging up newly planted corn and thus causing considerable annoyance and loss to the farmer. Probably, except for this injury in corn fields, they might be considered as beneficial rather than detrimental. They are not used as food, although

there seems to be no particular reason why they should not be as edible as the tree-inhabiting species.

The chipmunks are active little creatures common in stone fences and thickets, their habits being between terrestrial and arboreal, and while never seen in the tops of trees, they frequently are found on the trunks of trees at some distance from the ground.

The tree squirrels, such as the red, fox, and gray squirrel, readily climb to the topmost parts of trees and secure nuts which they store for winter supply. Their nests are constructed high up in the trees, usually in some hole or the upper portion of the trunk, or in some cases in the masses of dead branches or twigs that are held in a convenient crotch. Such nests are used to store food as well as to rear the young. They are quite commonly used as food and are considered very desirable pets in parks. The flying squirrels are still further specialized in the presence of a broad flap of skin at the side, extending from fore to hind legs, and this, when spread out, gives them sufficient surface, so that they can glide parachute fashion for considerable distances in the air.

One of the larger species, the common woodchuck, burrows in the ground and occupies a rather neutral position, since its attacks on vegetation are not of a very important character. Neither does it possess any commercial value, the fur being coarse and short, and its flesh is not used as food.

Prairie dogs are common species in the plains region west of the Missouri River, and the prairie-dog villages constitute a very striking feature, such villages including sometimes hundreds or thousands of burrows. In some cases they become extremely troublesome, ruining land for cultivation or so completely occupying it and killing the grass as to destroy it for pasture. The common practice for their destruction is to treat the burrows with carbon bisulphide, which is a very effective method. Aside from their destructiveness, they are very interesting creatures, and the relation established in the villages, which become occupied by owls and rattlesnakes as well as the prairie dogs themselves, is very interesting. Both of these other animals are undoubtedly unwelcome visitors

to the prairie dogs, and the old stories of the harmonious family including the three species in one burrow is a fanciful delusion.

Pocket gophers, *Geomyidæ*, constitute a quite distinct family of burrowing rodents, being characterized by the large pouches at the side of the head, these being formed by an infolding of the skin and capable of inclosing a man's thumb. The incisors are large and strong, the head much flattened, the front legs very strong, with the claws enlarged and fitted for burrowing, the hind legs shorter and smaller, and the tail short and scantily haired. They occur in the prairie region west of the Mississippi River, one

FIG. 264. — Porcupine, **Erethizon dorsatum**. Photograph from mounted specimen in Ohio State University Museum. (Photograph by Haskett.)

species occupying a large territory throughout Iowa, Nebraska, and Kansas, and another species occurring west of the Rocky Mountains in southern California. They dig extensive burrows of many rods in extent, and open these to the surface at intervals, partly for the purpose of disposing of surplus earth and in part for the sake of an exit, their forays above ground being mainly in the night time or else on dark, cloudy days. The mounds formed at the outlets of the burrows will often contain a half bushel or more of earth and cover a space of from one and a half to two feet in diameter and from three to six inches deep. The

hole itself is closed up by a mass of earth which is pushed out from the interior and is only cleared away at times when the gopher is unloading earth, or outside of the burrow. Gophers are often very troublesome on account of the covering up of the grass and also because of the numerous burrows making soft spots into which cattle or horses may step. They are exceedingly wary of traps, and it is a matter of some difficulty to reduce their numbers by trapping or poisons, but these methods can be resorted to with some advantage.

Porcupines are large rodents, approaching the beaver in size, and are distinguished from the other species mainly by the presence of long, stiff quills or spines which give a most excellent protection. These extend from the head over most of the back and along the upper portion of the tail. Porcupines feed upon vegetation, and their range is over the pine regions of northern United States and Canada. A closely related species occurs in Europe.

Order Cetacea. — Whales are among the most remarkable of the mammals, showing the most extreme condition of aquatic life, all of them being inhabitants of the ocean and without any dependence whatever upon migrations to land, even during the breeding season. A few species enter the mouths of rivers and a few live permanently in the large rivers like the Amazon and Ganges. Their form is fish-like and shows in every detail a distinct adjustment to the medium in which they live. Hair is wanting except for a few bristles upon the head. The legs are greatly modified, the front ones being represented by a pair of paddles, while the hind limbs are either entirely absent or are represented in extremely modified forms by the flukes which form the tail fin. The mouth in most species is extremely large, and, especially in those forms which depend upon straining out minute aquatic organisms as their food supply, is wanting in teeth, but is provided with a structure fitted for securing the minute animals which pass into the mouth along with the water. Like all other mammals, their respiration is entirely by means of the lungs, but they have acquired the ability to remain under water for an extreme length

of time, sometimes for at least thirty minutes, which enables them to reach an extreme depth. The nostrils are located on the upper part of the head, and the air exhaled through these, forms in frosty air jets of condensed vapor which has the appearance of fountains of water. The reproduction, as in other mammals, is viviparous, but apparently little is known regarding the early habits of the young. The mammary glands are located near the external genital opening. Of one of the whales it is stated that the usual number of young is one at a birth, and the period of gestation is apparently about a year, but for most of the whales there seems to be rather scant information regarding the breeding habits. The young in some forms are known to occur in schools with the adults, and while suckling the mothers lift the hind part of the body so as to bring it nearly out of the water. The group includes a large number of different kinds, occurring in different parts of the ocean, but the best-known forms are the sperm whale, which occurs in warmer waters, and the whalebone whale, which is a resident of the more arctic portions. The sperm whale retains the teeth during life, but in the whalebone whale the teeth which appear temporarily in the young become entirely lost in adults, and the mouth is provided with an immense number of horny plates, the whalebone, which split into innumerable fine strands and which together form an enormous strainer for the separation of the minute organisms in the water which constitute its food supply.

Formerly the whale fisheries were of very great importance, but with the utilization of mineral oil their importance has declined, although they have not been entirely abandoned. During the height of the industry, in the early part of last century, immense numbers of vessels with a very much specialized mode of operation were engaged in whaling, and for many years the Massachusetts ports, especially New Bedford, had the supremacy. In 1846 seventy thousand people were engaged either directly or indirectly in the whale industry, and the value of the shipping was given as above twenty millions of dollars, while the total investments

reached seventy millions of dollars. Since then these figures have been much reduced, and at present the industry does not compare with that of the cod fishery or a number of other industries based upon sea products.

Order Sirenia. — The dugongs, or manatees, or sea cows, are a peculiar group of mammals which are aquatic in habit, living entirely in sea water, or in the mouths or estuaries of large rivers, particularly in tropical waters. They have a thick skin, usually naked, but in some cases with scant hair. The legs are adapted for swimming, and much modified from the forms adapted for locomotion on land. The fore limbs are large, but the hind limbs are apparently entirely wanting, and the tail is flattened and closely connected with the body. The mammary glands are located near the fore limbs. The smaller forms are three or four feet in length, while the larger reach a length of eighteen to twenty feet. Their food consists of aquatic vegetation, seaweeds, rushes, and river grasses. The manatee occurs along the coast of the Gulf of Mexico, and the dugong is found in the Indian Ocean. The Steller's sea cow, a species which occurred in large numbers in the north Pacific, was so much sought for on account of its flesh that it was completely exterminated about the year 1768. The flesh of all the species is palatable, and is frequently used as food. Their numbers, however, are too small to constitute the basis for an important industry. Whether they could be cultivated or their multiplication encouraged by any artificial process, is a question which has not been especially studied, or, at least, no experiments in this direction are known to the author.

Order Insectivora. — These are for the most part rather small animals, and as the name indicates, are insect-feeding, although not absolutely confined to insects as a diet. Most of the species are inconspicuous, either hiding amongst the litter at the surface of the ground, or burrowing into the ground and living constantly in these burrows, feeding upon insects, earthworms, and other subterranean animals which are reached in their burrows. They have a pointed snout, small ears, and the fur in most species is

very fine and thick, but in the hedgehog includes a very dense covering of short spines or quills similar to those of the porcupine. Teeth are numerous, including incisors, canines, and molars, all of which are sharp and adapted for the insectivorous habit. The legs are short, and in the burrowing species adapted for digging in the earth.

The American species are the moles and shrews, and these are very generally distributed over the country. Of the moles, probably the most common is the silvery mole, whose burrows are often very conspicuous in lawns and meadows on account of the earth being forced up above the burrow, so that it may be traced sometimes for many feet. While the purpose of the mole is to secure grubs and underground insects as food, the injury to the sod is sometimes so great as to make them a great nuisance. It may, therefore, be necessary to destroy them in lawns, but in meadows and pastures they may be considered not detrimental. The shrews are similar mouse-like creatures, less noted for burrowing, and feeding in a somewhat more general manner, their diet including mice and small mammals, as well as insects and earthworms and other subterranean forms. The star-nosed mole is peculiar in having a star-like expansion of the snout. The European hedgehog is provided with a dense covering of spines, and in Africa there is a large species, the colugo, having a broad expansion of the skin on the sides, which enables it to soar in the same manner as the flying squirrels.

Order Chiroptera. — The bats are unique among animals in the possession of well-developed wings and their ability to fly, and seem to have their nearest affinities in the insectivora. They are short-bodied, with heads in most species rather short and blunt, and with prominent ears, small eyes, and often a dilated nose. The fore limbs are greatly extended, the digital bones being very much elongated, and forming a framework for a broad, flexible membrane which, when expanded, constitutes the wing surface. This membrane extends usually to the hind legs, and in some species there is a further extension between the hind legs and tail,

so that the extent of the membrane is many times that of the body. The hair, which is fine and thick, often extends on to the base of the wing membrane. At rest, the bats hang head downward, holding on to the support by means of the toe claws. They are incapable of walking, but may move about in an awkward fashion on level surfaces by the use of the feet and aborted finger at the base of the wing phalanges. The bones are slender and light, and the sternum possesses an extension similar to a keel for the attachment of the pectoral muscles, which are enlarged for their function in flight.

The group is not very numerous in species, but is distributed throughout the world, and contains fairly distinct divisions in which we note difference in food habit, some being insectivorous, others fruit-eating, and still others sucking the blood of warm-blooded animals. The species occurring in the United States are small, and all belong to the insect-eating group and may be considered as useful on account of the fact that the major part of their food consists of destructive insects. They are strictly nocturnal in habit, flying during twilight or nighttime, and depending upon catching their prey on the wing; hence their food consists almost entirely of night-flying insects. During daytime they secrete themselves in dark places under the rafters in barns, under bridges, in caves, or other secluded places. The young very commonly cling to the adults and may be carried by them in their flight. They pass a dormant period during the winter, but some species probably migrate some distance southward to secure more favorable conditions.

Order Ungulata. — This order includes a large number of familiar animals, the species being as a rule large, and they have been brought into domestication to a much greater degree than any other group of animals. It is only necessary to mention the horse, cow, sheep, goat, camel, and hog to indicate the extent to which the group has been made of service to man. Aside from this there are large numbers of wild forms, like the deer, elk, moose, caribou, antelope, etc., in America, and many equally important species in

the Old World. The group is essentially herbivorous, nearly all of the species depending entirely upon vegetation, and the others, which are somewhat carnivorous, using vegetation as the larger part of their food. The more striking characters are the presence of hoofs instead of claws or nails on the feet, the development of broad grinding molars, and for a part of the group a specialized alimentary canal. For our purpose here we may separate the group into two main divisions, which will include first the non-ruminants or the odd-toed ungulates, Perissodactyla, and the even-toed forms, mostly ruminants, the Artiodactyla. Of these the greater specialization of the alimentary canal would seem to make the latter the most recent.

Among the *Perissodactyla* the tapirs, occurring in South America and some parts of the Old World, represent a rather primitive group. They stand as a surviving group representing something of the character which probably pertained to the ancestral horses, although the separation is now very wide.

In the horse family there is a very extensive series represented in different parts of the world and including some of our most important domestic species. Of the wild forms, the zebra and quagga are at present best known, and of the domestic species the ass and the horse are familiar in every civilized country. The former has been used as a beast of burden for thousands of years, and, with the cross between the ass and horse, the mule, is one of the most important means of transportation. The horse is represented by a number of distinct races, some of which are now so well established and distinct that were they to occur in nature and their history unknown, we would have no hesitation in counting them distinct species. The larger Percherons and similar breeds contrast most strikingly with the Shetland ponies, while the Arabian, the thoroughbred, and the trotting breed represent distinct types selected along different lines, which have been bred to a very great degree of perfection for their particular purpose. The horse industry stands next to the cattle industry in importance, as judged from the value of farm animals represented

in the last census. While the horse as a means of transportation has been largely replaced by steam, electricity, and gasoline, it still remains as a very important factor in the work of the world, and will doubtless hold its place for a long time both as a source of pleasure and in certain fields of labor.

While all of our present breeds of horses are derived from Old World species and all of the wild horses of America are considered as derived from introduced animals, it is shown by the fossils of earlier geological periods that the ancestral line of the horse is represented in North America by many different species.

The genealogy of the horse has been worked out more completely, perhaps, than that of any other animal, and can now be traced from a primitive five-toed form which was not larger than

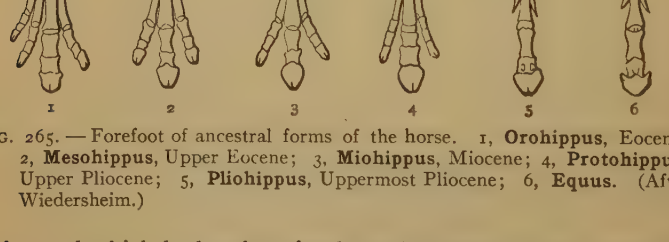


FIG. 265. — Forefoot of ancestral forms of the horse. 1, **Orohippus**, Eocene; 2, **Mesohippus**, Upper Eocene; 3, **Miohippus**, Miocene; 4, **Protohippus**; Upper Pliocene; 5, **Pliohippus**, Uppermost Pliocene; 6, **Equus**. (After Wiedersheim.)

a fox and which had rather simple teeth, through forms occurring in later periods that increased in size from that of the sheep or goat to that of the ass, and in which the toes were gradually reduced to three, and finally to one, with the last toes represented in the splint bones as they occur in the horse at the present time.

The *Artiodactyla*, or even-toed ungulates, include a large assemblage of important forms. The hogs constitute a rather extensive group, including the peccaries, wild boar, and common domestic hog. This latter at present is represented by a considerable number of quite distinct breeds, all of which probably trace their

ancestry back to the common wild hog of the Old World. This species forms the basis for a very extensive industry, many millions of animals being reared in the United States each year, and the investment in the industry runs up into hundreds of millions of dollars. Aside from the utilization of the meat in various forms, the blood and refuse is manufactured into fertilizer, the bristles are used for brushes, the skin as leather for footballs and other purposes requiring special toughness, while the bones, teeth, and hoofs are utilized in the manufacture of various articles. The deer and allied forms, including such animals as the moose, elk, etc., is represented in nature by a large number of species which occur in the unsettled portions of America, Africa, and Asia. A few, like the red deer of Europe and the Virginia deer in America, have survived within the bounds of civilization either in isolated, unsettled areas, or as a result of protection in game preserves. They are valuable for the meat as well as for the hides. The males have large spreading antlers or horns which are shed annually, and which, as they grow out, are covered with a velvety material which is the epidermal growth. This peels off when the antler is mature.

The antelopes occupy an intermediate position between the deer and cattle, possessing horns which are hollow instead of solid. The common American species occupies the plains region, and is noted for its fleetness. It is also well protected by its color, which blends in with the landscape so that at a little distance it is difficult to see.

The sheep and goats constitute another quite extensive division, distinguished by the long, fine wool and hollow horns. These have been introduced into all of the civilized countries, and constitute a very important factor in human life. Goats are utilized very largely in some countries as a source of milk supply and also as draft animals. The sheep are utilized to an enormous extent in the production of wool and meat.

The camel is a species having feet which are specially fitted for traveling over sand, being cushion-like and with very small,

nail-like hoofs. There is a large hump on the back (and in the Bactrian camel there are two humps), consisting of a large mass of connective tissue, including much fat. The nose is flat and the stomach is remarkable on account of the reticular character of the second stomach. Camels have played an immense part in

Fig. 266. — Grade Hereford Steer. From photograph by Prof. C. S. Plumb.

civilization, since they have constituted in the tropical countries of the Old World one of the most important means of transportation and communication between nations. The hair is used very extensively for the manufacture of fabrics and brushes. Related to the camels are the South American llama and guanaco, occurring in the Andean region, and kept under domestication by the natives of that region for an unknown length of time. Their

importance as a means of transportation for that territory is as great as that of the camel within its particular region.

The musk ox is a quite remarkable species adapted to arctic conditions and occurring only in the barren territory within the arctic circle. It is a long, heavy, bulky creature with extremely long hair, and is much prized for food by the natives in the northern region. It has never entered into commerce except as a rather rare specimen for museum purposes.

The buffaloes and cattle are characterized by horns, which are of bone, forming a core covered by horn, and the incisors of the upper jaw are wanting. They are animals of large size, and the different species are distributed throughout the world. The water buffalo is used quite extensively in portions of the Old World as a beast of burden and to some extent for its flesh. The common buffalo of Europe is now mainly extinct, but survives in certain sections. The American buffalo, or bison, has been practically exterminated from all the plains region, and is represented at present by a small number of individuals, most of these being protected in parks or ranges which have been set aside for the purpose. This species but a few years ago swarmed in countless numbers over the entire Mississippi Valley and plains region, but has now been brought to the verge of extinction simply because of the wanton, senseless destruction of individuals without any use being made of the animals. Their hides are of particular value on account of the dense hair, and buffalo robes were formerly one of the most common and useful articles for protection from the cold, and had the slaughter of the animals been confined to killing those necessary for the supply of robes, the species might have survived indefinitely. They were shot from moving trains, however, simply as a means of sport and were left to rot where killed. Attempts are being made with the remnant to build up herds in various places, and some success has been achieved in crossing the buffalo with cattle, the resulting cross sometimes producing an animal of very fine hair as well as a high grade of meat.

The ox has a history in domestication running back into the unknown past, and has been in all ages one of the most useful species to man. Our common breeds, which are now separated into forms for beef, milk, etc., doubtless trace their ancestry back to a common wild form occurring in the Old World. The use as beasts of burden was much more important in former times than at present. Important to-day are the use of the hides in a great variety of forms, and especially as foot wear and for harness and other purposes, the use of the flesh as food, and, most important of all, the use of the milk, with its various products, especially butter and cheese. Taking these different things into account, the cattle industry stands as one of the most important of the agricultural industries of the world, and in many countries, such as Switzerland, Germany, and Denmark, and for many states in the Union, is a leading industry.

Effect of Domestication on Animals

Animals of many different groups have been brought under control and more or less completely made dependent upon man, the more striking forms being such as are used most continually in his daily life. Of the lower forms, such as insects, but very few can be considered as distinctly domesticated. The honey bee and silkworm are both kept under a certain amount of control and have been modified in some degree by the care of man, but not in any such degree as is practiced with cattle, sheep, horses, etc. Of the other invertebrate animals none can really be termed domesticated. Of the lower vertebrates, fishes are the only ones which could be considered as in any sense brought under control, and but very few of these are utilized in any very distinct manner. The German carp come perhaps nearest to being under complete control of man, although trout, goldfish, tench, and a few other forms are fairly well under control. Among the birds a number of species, such as the pigeon, turkey, pheasant, guinea fowl, and especially the common hen, have been utilized for long

periods of time and very considerably modified by the care of man. This shows particularly in the pigeon and the hen, which doubtless have been domesticated for a much longer period than other species. Our wild turkey, for instance, which formed the basis for the domesticated form, has a history of domestication of not more than four centuries, and shows less departure from the original form than is to be observed in the breeds of chickens. Cattle, sheep, swine, horses, donkeys, cats, and dogs have all had a long history of domestication, and in some instances it is practically impossible to determine what the original wild stock may have been. This is especially true of the dog, the original stock of which may have been represented in several closely allied species. One effect of domestication has been the production of numerous races or breeds, which have become more distinctly established with careful selection, and many of these are now so distinct that they would be considered species, if observed under natural conditions. It is to be noted also that in many of these species one result of domestication is to make the animal so dependent on the care of man that a return to natural conditions would be almost impossible. For instance, our fancy breeds of chickens, and some of the breeds of dogs and cattle, would find it extremely difficult or impossible to survive, if turned loose to shift for themselves under conditions such as they had before domestication. We have, therefore, alongside of the distinct advantage that these animals secure from the care of man, the limitation of their powers and the loss of the ability to care for themselves.

Order Proboscidia.—This group, including the elephants, is now represented by only two species, but they were formerly represented by a considerable number of massive animals, of which the persisting species are quite typical. They have large bodies supported on pillar-like legs, an extreme prolongation of the snout to form a flexible and very muscular trunk which bears at the end the nostrils, and also a flexible, finger-like process used for prehension. The upper jaw has two enormously developed tusks, and the molar teeth are broad and provided with numerous grind-

ing ridges. The skin is tough and scantily haired, and the feet are provided with broad, nail-like hoofs differing in number in the two species.

The elephant of the present time occurs in southern Asia and Africa. The species occurring in these two regions differ in several quite distinctive features. The Asiatic elephant possesses the greater number of hoofs, having five in front and four behind, while the African has four in front and three behind. The latter has ears of larger size and larger tusks. The African species usually has a darker-colored skin and is less susceptible to domestication. The Asiatic elephant has for many centuries been kept as a domestic species, and in some countries of eastern Asia is still a most important domestic animal, being used mainly as a means of transportation, but also for tiger hunting and such purposes. In this country they have their most conspicuous service as members of the zoological gardens and traveling menageries.

Of the extinct species the mammoth was the largest one, and this probably was the largest of all land mammals, some of the individuals reaching a size which was much greater than any of the existing elephants. Many individuals have been found in the arctic regions encased in ice so that their entire structure has been perfectly preserved. They were provided with long, dense hair. The mastodon, from the frequent discoveries of bones throughout the northern United States, must have been a quite common animal, ranging over a large portion of North America, and was somewhat larger than the largest elephants. Their tusks were very long and considerably curved.

The tusks of the elephant have an important commercial value as ivory, and the collection of these tusks has formed a large industry in Africa, and has been one of the important factors in the white invasion and exploitation of the natives in that country. To secure the ivory, immense numbers of elephants are slaughtered annually, an estimate made some years ago placing the annual destruction at about a hundred thousand. At this rate the practical extermination of the species seems inevitable, and consid-

erable effort has been made on the part of naturalists and sportsmen to secure enactments which would regulate the number that may be killed so as to avoid the extermination of the species. Elephants breed but rarely in captivity, and the great majority of those domesticated are captured and brought under training, so that the supply must be kept up by continuous captures of wild animals.

Order Carnivora. — This, as the name implies, includes the flesh-eating animals, and the group as a whole is restricted to this form of diet, although some of the species may at times include other articles in their food supply. While in many features, especially in the teeth and feet, they are much less specialized than the ungulates, they have a quite high degree of organization, and since they are more directly in the line of groups which culminate in the primates, it is convenient to place them nearer to that division. The bodies are usually covered with dense hair, often forming a soft fur, and they are frequently spoken of as the fur-bearing animals. The teeth are sharp and fitted especially for catching and tearing prey. The canines are large, while the incisors are commonly much less fully developed. The molars, while somewhat flattened, are usually provided with distinct tubercles and have little adaptation for grinding of food. The alimentary canal is simple, correlated with the flesh diet. The feet have usually five or at least four toes, and the toes are provided with sharp claws which in the cat family are distinctly retractile.

The group is quite an extensive one, and is represented in all parts of the world, and in many regions includes the most dominant forms of animal life, outside of the human species. Comparatively few, however, have been domesticated, but the common cat and dog show the extreme possibilities in this direction, both of these forms having been associated with man from earliest historic time, and remnants of their bones appear to indicate something approaching domestication in connection with the prehistoric races.

Fissipedia. — Among the land carnivores the group of bears includes some of the largest species. They have a wide range, and

are much less strictly carnivorous than most of the other members of the order. In fact, many of the species, such as the fruit bear, and even the cinnamon and grizzly and the common black bear, feed to a considerable extent upon grain or fruits or different forms of vegetation that are in season. They are dormant during the winter, usually becoming very fat in the autumn and surviving in a very torpid condition through the cold winter, existing on the food supply stored as fat in autumn. They have long hair, the nose is usually prolonged, the feet are plantigrade, and in many species there is a distinct ability to stand upon the hind legs and use the fore legs in capturing food supply or in defense. Most of the species are comparatively harmless except on provocation, but some forms, especially if irritated, are very dangerous. The black bear or brown bear is in different variable forms distributed throughout the entire northern hemisphere, and is a very common form in confinement. It becomes quite docile, and in fact may be considered as at least semi-domesticated. The grizzly bear of the Rocky Mountain region and the Alaskan bear are huge animals of enormous strength, and certain individuals sometimes are very ferocious. The polar bear, confined to the arctic regions, is another very large species, and one which shows a considerable amount of adaptation for aquatic life, being able to swim readily and to capture fish as a food supply. Its white color is an excellent protection among the icebergs and snow fields which are its common habitat.

The common "coon," or raccoon, is related to the members of the bear family, and exhibits many of the same traits, but its small size and comparatively friendly habits make it an object of interest rather than aversion. The raccoon fox of the Pacific region and the coatis of Brazil and Mexico are related here and present similar habits.

The skunk belongs to a family which has a rather extensive distribution, especially in the northern hemisphere, and it is characterized by the development of strong scent glands which have given it a distinct reputation. Barring its unsavory character, it

has a quite important place, since it is of public service in the destruction of many forms of insects and destructive mammals, such as mice, and besides, it furnishes a very valuable quality of fur. In recent years this has led to the establishment of skunk farms, which are said to be quite profitable.

The sable, mink, ermine, and weasel all appear as important fur-bearing species, forming the basis for a most extensive commerce, and have further a distinct economic importance, being useful in so far as they prey upon destructive forms of animals, and detrimental when they direct their attacks upon poultry or animals which have a value to mankind. The ferrets, which have been brought into domestication, are similar to the weasels in slenderness of body and the ability to creep into small burrows for the capture of rats, rabbits, etc. The badger, once a fairly common species and valuable for its fur, has become quite rare.

The foxes, wolves, and dogs form a fairly distinct family, the Canidæ, in which the more distinctive characters are the length of the legs, with a corresponding elevation of the body above the ground, a pointed nose, prominent ears, and long and frequently bushy tail. Different species of foxes occur throughout extensive regions, and furnish a valuable product in the form of pelts, but are also seriously destructive at times in their attacks upon poultry. The wolves, larger and more ferocious species, are quite similar to dogs in their habits. The coyote, or prairie wolf, roams over an extensive area of the western plains, and was formerly a most conspicuous factor in the plains fauna. Its numbers have been very greatly reduced by persistent destruction, following settlement, but it still persists in the less settled portions of the area west of the Mississippi River. It is much less ferocious than the timber wolf, and depends largely upon jack rabbits and prairie dogs and similar animals of the plains region for its support. The timber wolf, formerly common throughout the timbered regions of North America, has become less and less common, and in many of the states is entirely exterminated.

The domestic dog, which is now represented by a large number

of distinct breeds and an innumerable number of mongrel strains, may have had its origin in some one species occurring in prehistoric times, but it is quite possible that it represents a mingling of two or more nearly related species. Among the more conspicuous breeds at present are the St. Bernard, Scotch collie, spaniels, hunting dogs, pointer and setter, greyhound and bulldog.

FIG. 267. — Tiger, **Felis tigris**. Photograph from mounted specimen in Ohio State University Museum. (Haskett photograph.)

Many of these, when bred with care, retain characters with almost specific certainty, but nearly all of the breeds may be intercrossed indiscriminately with other breeds, and the hybrids thus produced are fertile, and further breeding with them usually results in a continuation of the mongrel characters.

The hyenas occupy a somewhat intermediate position between dogs and cats, having a rather large, bulky body and having long

legs and the body features of dogs, but with much larger and a less pointed nose. The jaws are very large and strong and armed with large teeth. Their habits are rather as scavengers than as predatory forms, and their distribution is limited to portions of the Old World.

The civet cats are rather slender forms, with long nose and dentition closely related to that of the cats, but some of the features are decidedly dog-like. They belong entirely to the Old World fauna, and have some value on account of the fur, and also for the scent glands, which are utilized for perfumes. For the purpose of securing this article some of the species are kept in captivity.

The cat family proper includes a number of very striking species, and in the lion and tiger represents some of the most dominant forms. The lion, while usually termed the king of beasts, is inferior to the Bengal tiger in strength and endurance, and the title properly belongs to that species, if it is based upon the relative prowess of the two species.

The lion is distinctly an African species, roaming through extensive parts of the Central African wilderness, while the Bengal tiger is the undisputed monarch of the jungles of southern Asia. Aside from these forms, there are numerous smaller species of tigers and leopards, panthers, pumas, lynxes, and wild cats which occupy an important position, and which are important species in their attacks upon domestic animals and on account of the large danger they may be to man in some localities. Some of them are dangerous only when enraged or in need of food, and may to a large extent be of service in keeping in check other forms of animals which might in too great numbers be injurious to human interests. The common domestic cat has a close relative in the European wildcat, from which some authorities believe it to be descended, but in that case the domestication must have occurred at a period so remote that the two forms are now widely separated; in fact, evidence is abundant for the occurrence of the cat in domestic form at least four thousand years ago, and the actual

process of domestication must have been in progress for many previous centuries. At present the domestic species is represented by a number of breeds which have quite distinct characters, the Maltese, Persian, Angora, and Manx being some of the most distinct varieties. The tailless cats of the Isle of Man are best known, but a tailless variety occurs also in the Crimea. The absence of tail is correlated in these with a relative shortening of the sacrum. Cats have a distinct value as a means of control for rats, mice, and other destructive mammals, but they are kept at present very largely as pets, with little reference to their economic value. The fur is soft and is very extensively used in the manufacture of some of the cheaper grades of gloves, furs, etc.

Pinnipedia. — The members of this group are aquatic in habit and represent a branch of the Carnivora in which special

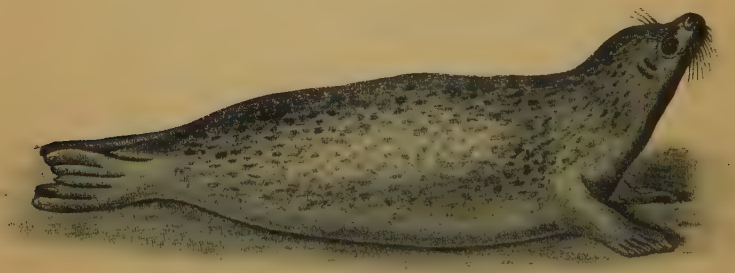


FIG. 268. — Harbor seal, **Phoca vitulina.**

adaptation has been developed in the direction of aquatic life. There are among the other carnivores some species, such as the mink and otter, which show aquatic tendencies, but in these there has been no such important modification of structure as is recognized in the members of this group. These must have become aquatic in habit at a much earlier period, and have thus undergone much more extended changes in structure. Of these the seals and walruses are the most conspicuous forms, and among them are species which show different degrees of adjustment to the

aquatic life. In all of them there is a modification of the front legs into paddle like appendages, with a great modification of the fingers and considerable development of web and reduction in length. The hind legs are still more specialized, being developed into large flippers and serving as the main organs of locomotion in water, and being practically useless for movements on land. The hair is usually short but very thick, and in the fur seal becomes remarkably fine and dense, giving it great commercial value.

The harbor seal is the common species of the northern Atlantic coast, and the sea lion, which is a common object of interest in the zoological gardens, belongs to the Pacific coast, an abundant colony occurring on the coast of California. The Steller's sea lion occurs in the northern Pacific Ocean; it is a large animal, sometimes weighing as much as twelve hundred pounds. The northern or Alaskan fur seal is the most important commercial species, and presents many very interesting habits. Its summer residence and breeding ground is in the Behring Sea and is confined mainly to one or two islands, where it congregates in great numbers and where its capture has been carried on for many years. In the hope that the colonies may be preserved as a permanent source of income, the capture of individuals in the open sea, which affects mainly females, and which has resulted in a serious depletion of their numbers, has been prohibited, and the protection of the seals from this form of capture has resulted in much controversy between those countries interested. During the winter season the seals are absent from this region and their whereabouts is a matter of much speculation.

The seals, during the breeding season, live in groups, a single old male collecting a harem including from five to fifteen or twenty females, over which he exercises practically absolute authority, and defends them from other males which might attempt their capture. The young seals are born during midsummer, and grow rapidly during the summer to a size sufficient for them to survive in the winter. Most of the young males, and all of those a year

FIG. 269. — Alaskan seal, **Calorhinus ursinus.** Photograph from mounted specimen in Ohio State University Museum. (Haskett photograph.)

or two of age, herd by themselves and only assume the duties of heads of families when reaching the age of six or more years. The females under three years of age do not breed. This species of seal represents, therefore, a very greatly specialized condition of polygamy, and associated with this is an enormous difference in the size of the sexes, the males being six or eight times as large as the females, and having an enormous development of the neck region. In the fights between the males the strength of the neck

muscles and jaws is an important factor, and has evidently been intensified and developed by natural selection. The fur-seal industry represents many millions of dollars, and the decreasing number of valuable seals and the extravagant prices reached by the furs has resulted in a great diminution in the traffic.

The walrus is one of the largest members of the group, and is characterized by two large tusks extending abruptly downward from the upper jaw. It reaches from ten to twelve feet in length and is a very unwieldy animal on land. The hair is scant and short. It is much used in northern countries, the natives making use of the flesh, fat, and hides. A number of less important species of seals occur in different regions. The sea elephant is a very large form, the largest of the true seals, and of greater length even than the walrus, some authors recording individuals of from fifteen to twenty and even twenty-five to thirty feet in length. The male has a proboscis of about fifteen inches in length, which shows some degree of flexibility, though by no means so adaptable a structure as the proboscis of the elephant.

Order Primates. — This group is placed at the head of the animal kingdom, since it includes the human species, but it takes in also a number of much less specialized forms, and some of the most primitive of these can hardly be accounted as equal in rank to the more specialized forms of carnivores or ungulates. In the culmination of brain development and intellectual faculties the human species outranks all other groups, and must unquestionably be considered as the climax of the mammalian groups. The general characters are found in the presence of five fingers and five toes, the inner finger and toe being more or less distinctly opposed to the others, and in the hand assuming a grasping form. The nails are broad and flattened, only a few of the most primitive forms having them shaped like claws. The mammary glands are located in the pectoral region. The eyes are directed forward and the field of vision overlaps. In most forms the arms and hands are used rather for grasping and prehension than for locomotion, this feature in the higher forms becoming associated with an erect position.

In general, the members of this group are adapted for forest life, some of the species being very strictly arboreal. One of the characteristics of the group is the ability for adaptation to quite widely varying conditions of existence. It may perhaps be sufficient to sum up the characteristics in the statement that in general physical structure they are not more specialized than many of the other groups of mammals, but that they represent the highest degree of development of brain and mental characters. The group includes a considerable number of subdivisions having particularly distinct characters, and they have been variously classified by different authors quite largely as a result of the different opinions as to the distinctness of the human species from other mammals.

The division **Lemuroidea**, including the lemurs, is the most primitive, and includes small animals that use all four limbs in locomotion, the primate characters appearing in the position of the thumb and great toe. In size they vary from that of a mouse to that of a fox, many of them being quite handsome little creatures. They live in trees often in large groups and are found particularly in South Africa and on the island of Madagascar.

The **Anthropoidea** show considerable advancement from the lemurs in the development of the brain and in the human characters. The monkeys, marmosets, baboons, etc., use all four legs in locomotion and all are provided with long tails, in some cases the tail being used very extensively as a prehensile organ. Their distribution is mainly through the tropical regions of the Old and New World, and the inhabitants of these two regions are separated by quite distinct characters. The New World species are characterized in general by the broad nose, with conspicuous nasal septum, while the Old World monkeys have this septum quite narrow, and the nostril consequently directed forward rather than outward.

The larger and most man-like of the group, called **apes**, are represented by three well-known species, the orang-outang, chimpanzee, and gorilla. These all have the tail aborted and arms and legs of

considerable size, the relative length of the arms, especially in the chimpanzee and gorilla, being greater than in man. Of these three species the gorilla is the largest, and in some of the physical traits is perhaps most nearly related to the human species. The orang-outang occurring in Borneo and adjacent islands approaches man in size and presents many human characteristics, but shows much less intelligence than the chimpanzee, which, although perhaps the most inferior in size, is the most intelligent of the three species.

These species, while resembling the human species in many characteristics, must, of course, be recognized as having evolved along special lines of their own, and none of them are to be thought of as the source of the origin of the human species. While all the evidence derived from the characters showing the evolution of the human species points to its origin from some anthropoid form, this origin must have been at a remote period, and the other species associated in the same regions were undoubtedly undergoing modification and adaptation to particular conditions in the same manner, if not to so great a degree, as man. It is futile, therefore, to look for the primitive stock of the human species in any existing animal, and the speculation as to which of the anthropoids may be our nearest kin can have but little value with reference to the derivation of the human species.

The human species, standing at the head of the extensive series of mammals, apparently had its origin somewhere in the Central Asiatic region, and so far as can be determined by present evidence the different races of mankind as now recognized had a common origin. The distribution of these races, to cover the extensive regions of the earth's surface and to bring them into different climatic conditions, resulted in the development of racial types which have become to a large degree fixed. The races, however, are not widely separated, and the mingling of different races which has been much more common during the recent centuries, has undoubtedly had the effect of producing types of the human species different from that existing in previous ages.

The adaptation of the human species to the different conditions

met with in different parts of the earth, the development of means of communication, the effects of commerce, the development and specialization due to the shifting of races from place to place, the rise and decline of different nationalities, the dominance and submergence of many different peoples, — all constitute a most fascinating field of study, but these belong to the province of **anthropology** or **sociology** rather than to zoology in its more restricted sense. It has been our purpose to trace the development of the different groups of animals and to indicate their relation to man in his many varying interests and to glance at these different relationships. A little thought concerning the influence which man himself has had in the control of some of these lower organisms will emphasize the importance of this relationship, showing not only the great dependence which man has upon other forms of life, but also the fact that, as the present dominant animal, he has been a most important factor in the distribution and cultivation or destruction of many inferior species.

CHAPTER XXI

GENERAL SUMMARY AND CONCLUSIONS

Distribution

When we observe the occurrence of animals of the same species in widely separated parts of the earth, we naturally question as to the meaning of such a distribution. We assume from the general facts of animal life that these widely separated individuals must have descended from a common ancestor, occurring far back in time, and that the distribution into these widely separated points has been effected either by the natural spread of the individuals of the species or by some accidental or artificial transfer. This leads us to consider the means by which animals may be scattered and the barriers which serve to separate the different faunal areas.

Each species evidently has a tendency to spread over all the territory possible by its natural means; that is, to occupy as much of the territory as is possible, considering the limitations of land areas, or of water, if aquatic, the occurrence of high mountain chains, or of deserts, or other natural obstructions to its distribution. The main barriers may be considered as extensive bodies of water for land animals, or of continents or connected land for the aquatic species. Mountain chains or high elevations, deserts, and the limits of latitude or of climate may also affect the possible extension of certain species. This may in many cases be associated with the distribution of the food supply of any particular form. As a means of overcoming these barriers there are certain natural agencies, such as the oceanic currents or movement of water in rivers, the winds, and the migration of birds, which may serve as agencies of dispersal. For many forms of animals there is a more potent agency in the transfer of various forms of life

from country to country by means of commerce. This agency has become more and more potent as the commerce of the world has increased, and at present there is a very great and perhaps constantly increasing tendency toward the transmission of all kinds of animals to all parts of the earth. This is more particularly true of those forms which associate themselves with such products or articles of commerce as are most commonly shipped from port to port. A particularly important agency is found in the distribution of living plants which frequently carry the insect pests that infest them in their native country.

It is a matter of importance, therefore, to understand the different geographical regions or the limitations of the areas in which certain kinds of animals have their native distribution. Zoologists recognize five principal regions — the Palearctic, including northern Europe and Asia; the Nearctic, including North America as far south as Mexico; the Neotropic, including Middle and South America; the Oriental, including southern Asia; the Ethiopian, including Africa except the extreme northern border; and the Australian, including Australia and New Zealand. It will be noted that the barriers between these land areas are in some places very complete, formed by extensive areas of water, but that in some instances, as between the Palearctic and Oriental, and the Nearctic and Neatropic, the division is one of latitude or climate. Within these areas there are great numbers of animals which may be peculiar to the particular region, and which, if found in other regions, have doubtless reached them by artificial dissemination. Further, within these general regions there are minor divisions based upon divisions resulting from mountain chains, from elevation, latitude, climate, etc. Moreover, the divisions for any group of animals depend in some degree upon its habits and powers of dispersal. Birds may pass freely from one of these minor divisions to another, or even from one to another of the main regions, but fishes and mollusks occurring in certain river systems may be strictly limited to the particular watershed in which they occur.

There are somewhat similar limitations for marine animals,

many kinds of fishes being restricted to the shores of certain countries and utterly unable to pass across the oceans separating these shore lines. A further kind of distribution may be found in the ocean with regard to depth, some animals, the **pelagic**, being confined to the surface, others at moderate depths, and still others, the **abyssal**, restricted to greater depths, in their distribution.

The wide distribution of certain species may be illustrated by considering the present distribution of the human species, covering every habitable portion of the earth and represented by an immense number of races or minor racial types. Notwithstanding the extreme distribution and the great difference in type between such races as the Mongolian, African, and Caucasian, it is believed that the races all arose from a common ancestral form, and that the distribution throughout the world has been going on since the time of the first appearance of the human species.

It may be easily realized that the factors of distribution and the particular means of dispersal are of the utmost concern to us, both in connection with the successful colonization of man in different parts of the earth, and in connection with the dissemination of animals useful or inimical to human interests. One of the most important features of economic zoology at the present time is connected with the study of the means by which the introduction of detrimental forms may be prevented.

Artificial Dispersal

Connected with the general question of geographical distribution is the particular phase of distribution brought about by the artificial conditions in commerce and the distribution of different plants and animals from one country to another. As already mentioned, there is apparently a tendency among all animals to extend their range of distribution, and this doubtless lies at the basis of all phases of distribution. Connected with it are adaptations to different physical environments and ulti-

mately the evolution of distinct forms. In the introduction of foreign species into a country, there always arises a set of conditions which differ from those previously existing. In such cases as the introduction of the Hessian fly, the imported cabbage worm, the English sparrow, gypsy moth, brown-tail moth, domestic mouse, rat, etc., we may determine parallel cases of response to the new conditions which they meet. There is a general tendency for all these introduced species to displace or usurp the place of the native forms adapted to the same conditions of life. This may be due to greater virility of introduced form, to greater energy induced by change, to the leaving of certain natural checks or enemies behind them, or to a combination of factors in environment that stimulate vigor and productivity. Thus it happens that a large proportion of our most destructive animal pests have been introduced from the Old World.

In a natural condition the result of many centuries of adjustment between different organisms is the establishment of a sort of balance so that no one is likely to predominate. With the advent of civilized man, with his wants and methods of cultivation, this natural balance is greatly disturbed. Large plantings of single crops occur, the woodlands are deforested, the course of streams may be changed, large areas of swamp may be drained, turf is turned to tilled fields, wild animals, birds, etc., largely destroyed.

The large growth of certain kinds of favored food makes increase of certain forms possible. Destruction of woodland forces many forms to adapt themselves to new kinds of food and shelter or suffer possible extinction, and a host of destructive forms concentrating on the introduced crop make its culture increasingly difficult.

It is evident that great care should be exercised in the introduction of any foreign species; not only are its habits in its native country to be considered, but any possible change due to new conditions. Rabbits in Australia became a scourge because of lack of carnivorous animals of sufficient strength to keep them

in check. The English sparrow in America has become a pest in all our cities, largely occupying the place of common native birds. The mongoose, in the West Indies, introduced to kill rats, has itself become a pest.

The successful introduction of *Vedalia* to combat the cottony cushion scale in California was based on knowledge that it preyed upon this species in its native habitat, Australia, but very few of the many efforts in the same direction for other pests have proven successful. Many known species injurious in other countries, not yet brought to America, may be kept out, or their introduction probably delayed many years, if proper steps be taken to secure exclusion. The outlay already incurred in attempts to control the gypsy moth, not to mention the actual losses from its devastations, would be sufficient to maintain a quarantine system for probably very near a hundred years. But this one insect is a trifle compared with expense and losses entailed by San José scale, Hessian fly, codling moth, cabbage worm, sheep scab, and other widespread introduced pests.

Two policies are open: one, to inaugurate a system of exclusion, or at least of surveillance directed against animals that are likely to prove disastrous to our agriculture and commerce; the other, to recognize the fact that such forms are continually reaching our ports and being established in various sections of our country, and to begin intelligently to determine their capacities for damage and to learn to apply measures for their control. Both may be necessary, but energetic efforts on the first plan and adoption of rigid quarantine measures may greatly lessen requirement in the second.

These statements have been written with American conditions more particularly in mind. They apply to any country, but more particularly to those in which a new influx of population, with introduction of new crops and new forms of animal life, is in process. Australia and South Africa both present similar problems, and perhaps, in less degree, every geographic region of the world.

Modern commerce, with all its attendant blessings, affords most ready opportunity for the dispersal of many organisms that are inimical to human interests, and the only means of averting loss is intelligent recognition of the sources of danger and adoption of wise precautions to avoid or to minimize the loss as much as possible.

Adaptation

Having noted the fact that there has been a great development and distribution of animal life on the earth, we must appreciate that this has been associated constantly with an adjustment of the varied forms of organisms to particular conditions, an adjustment or **adaptation** that implies a close dependence of the organism upon the combination of conditions permitting its survival, and in many cases a restriction to a very limited or specialized set of conditions — such, for example, as the parasitic flukes, tapeworms, and the animals living in deserts, in hot springs, or in caves. Now we can conceive these adaptations as meaning a gradual acquisition in course of time of the special limitations, and we feel justified in assuming, from all the evidence available, that this adaptation is from the more general to the more special, but the precise factors are doubtful. One view, the **Lamarckian**, is that the effort of the animal, its use or disuse of certain parts or organs, is a prime factor in causing the development or reduction of such a part, and admitting the possibility of such modification being of influence in determining the character of the succeeding generation, there would appear a tendency to develop in a certain direction — **determinate** evolution. Opposed to this is the Darwinian view of **natural selection**, based on the occurrence of an indefinite number of variations in an indefinite number of directions, and assumption that, of the large number of individuals born, those with variations fitting the animal better for survival under the conditions of its environment, would be preserved, and hence this character held by selection to be

intensified by similar selection in succeeding generations. Adaptation in either case means **variation**, and hence the causes of variation have been of prime importance for study.

Variation

This is one of the most evident facts of living things, so constantly observed that we confidently assert that no two organisms are absolutely alike; but the reasons for this variation are so obscure that with all the study given to it we are still ignorant as to the underlying causes. We can see that such factors as difference in food supply affecting size, of space affecting form, of pressures affecting density, of light affecting color or pigmentation, may all have their influence; but recognizing all known factors of this sort, we have some unexplained variations. One factor, which doubtless must be accorded importance, is the union of two unlike parents in sexual reproduction, since, as a result of this **Amphimixis**, the progeny may vary from both parents or present characteristics of both.

Variations may be slight and occur in some degree with every generation — such are called **continuous**; or there may occur occasional extreme variations — among domesticated forms termed **sports**, or in nature **discontinuous** variations or **mutations**. In all these phases of variations it can be seen at once that so far as evolution of new forms is concerned, they would be ineffective unless perpetuated or passed on to succeeding generations, and this brings us to the question of *Heredity* or *Inheritance*.

Heredity

Perhaps even more evident and universally recognized than variation is the fact that animals tend to reproduce organisms like themselves, each "after its kind," and this repetition or **inheritance** of characters usually extends to the minutest details of structure. So perfect, indeed, is this repetition, that the earliest drawings or descriptions show exact details of present forms.

Skeletons of animals buried thousands of years ago among the débris of the mound builders are practically duplicates of the skeletons of existing species. Some insects, preserved in rocks of the Tertiary period, are almost identical with those of to-day, and in a most extreme case, that of *Lingula*, we have an animal appearing in the early Paleozoic, and remaining practically unchanged to the present time. Inheritance, then, is in one sense the antithesis of variation. It tends to hold all forms to the established type; variation, to depart from the type. Without variation there could be no progressive evolution, and without heredity no preservation of the adaptive features that serve the animals better or permit them to enter permanently into new phases of existence.

With non-sexual reproduction it is natural to expect the animals resulting from division or budding to retain the features of the parent form, and this may be looked upon as inheritance in its simplest form. In sexual reproduction, however, with its attendant processes of complex fertilization and development in egg through embryonic stages, it appears much more remarkable that the embryo should travel over the same developmental route and arrive at the same adult form as the parents, and the laws of this inheritance have been the subject of much investigation. While there is much yet to discover, and the subject is too complex to discuss fully here, some of the better-established principles may be reviewed. In the first place, we may now confidently believe that the basis for the repetition or inheritance resides in the germ cells of the parent animals, and that both parents contribute their influence in the characters transmitted to the progeny. Of the germ cells the nuclei, and especially the chromatin, seem to be the chief factor in transmitting parental traits. The parental characters may or may not appear in equal proportion in the direct progeny, and the ratios of such appearance are indicated in the terms "direct," "indirect," "alternate," "blended," etc

Of the various forms the **Mendelian** inheritance has been most fully explained. It is most evident in such external characters

as present strong contrasts and are termed **unit** characters, such as color of covering, and straight or curly hair or feathers. This principle, announced by Mendel in 1862, but not generally known till the present century, is, that for such characters there is a repetition in the first hybrid generation of the characters, as shown in one parent, and termed **dominant**, the one not appearing or **recessive** being present or preserved in the germ cells and reappearing in the second generation derived by crossing these hybrids. Moreover, this reappearance in the second generation follows a definite rule, one fourth of the individuals being of the pure dominant form, two fourths blended, and one fourth pure recessive.

What is Evolution?

Inasmuch as there is so much discussion regarding the factors of evolution or the various theories that attempt to explain it, we are liable to fall into the notion that the principle of evolution itself, or the doctrine of descent, is still in a debatable position. On the contrary, our knowledge of evolution, our certainty of it as a principle of nature, and our actual reliance upon it in all of our biological reasoning is more firmly fixed than ever before. If there is any general fundamental principle in biology that we may rest upon with security, it is that of the gradual development of life according to the general principle which is termed evolution. Evolution involves simply the descent of the present existing forms of life from preceding ones through an indefinite number of generations and with gradual modifications, all existing species being considered as descended from species of varying degrees of difference which existed in times past. While the evidences of the general principle have been frequently and carefully stated, it may be worth while to sum up briefly some of the most convincing facts which give us this assurance.

In the first place, we have only to recall our observations through a greater or less space of time to appreciate that the animals exist-

ing to-day are the descendants of those of yesterday, those of yesterday of the day before, and so on back in time into the remote past. While it may not be demonstrated, we have every reason to believe not only from the present facts that may be observed and demonstrated, but from the collective testimony of different sources of information, that this process has never varied during the progress of life development, but that there has been an unbroken series of generations throughout the time which life has been present on the earth. This need not mean an unswerving rate of variation, for it is entirely possible to conceive of periods of such accelerated or retarded evolution without in any sense involving a break in the general series.

Again, we have unquestioned evidence of the modification of the animal species in the development of various breeds or races of domestic animals, many of which can be traced not only in the observations of a single lifetime, but more completely by means of historic evidence of the most reliable character. So true is this that probably no one thinks of questioning the derivation of the breeds of our horses, cattle, sheep, swine, dogs, cats, and poultry from former wild species, differing widely in character from their progeny of to-day. Here, alone, would be a positive case of evolution in a particular series of organisms. Similar evidences appear in the case of cultivated plants and perhaps fully as striking evidence in the various races of mankind. Modern man differs in many striking particulars from the man of other historical periods, but we never think of questioning our derivation from the earlier races or nationalities.

The evidences of similarity in structure, the proofs from comparative anatomy, while of a different character, are to the anatomist almost equally convincing. The identity or close resemblance of the different bones forming the skeleton in different species, many orders, and even classes of vertebrates, when taken in the aggregate, furnishes so well known a mass of evidence that a common origin seems inevitable unless the whole significance of such similarities be discarded completely. Rudimental, vestigial,

abortive organs, and those in which there has been evident change of function, all testify in the most emphatic terms not only to modification in the particular series in which they appear, but of affinity to other groups in which they have different development.

The development of the individual, itself a most distinct evolution, is, when it is compared with the phylogenetic series, possessed of striking significance. Every organism begins as a single cell and develops by the process of evolution through various and numerous intermediate steps up to some particular terminal point. Often in these stages of development there appear most striking resemblances to organisms that are the mature forms in other groups. Such duplications or repetitions might be conceivable in a few instances as mere matters of coincidence, but when they occur in some degree in practically every organism that may be studied, the conclusion that they have some fundamental significance is inevitable. The whole evidence of embryology is most strikingly assuring in the matter of an evolution of each species of a group from single ancestral forms to its present condition. In fact, every time we watch the growth of an individual from egg to adult, we are actually watching an evolution. The only question is, whether the evolution in such a case is actually indicative of the evolution which gives rise to new species.

Another entirely independent line of evidence is furnished in the remains of animals which have existed in past time and which have been preserved in the rock formations of different ages. Their position, structure, and relation to earlier and later periods most positively indicate them as evidence of incontrovertible character. Whatever the possible variations of interpretations offered for these fossil forms, there appears to be the most perfect agreement amongst palæontological students that this evidence shows a gradual perfecting of animal organisms from period to period, a certain derivation of these for each period from those of the preceding age — in short, a distinct continuity of living organisms from age to age.

Each line of evidence mentioned above appears to the workers

in that particular field to be conclusive, but, if we put these together, by the corroboration which they afford each other, the strength of each is greatly increased.

It may be said, then, that evolution is to be looked upon as a fundamental principle in nature, a process in life development, a method of growth which is just as essentially fundamental as the principle of gravitation in regard to mass.

Admitting, however, these established views regarding evolution, it is evident that the particular factors concerned in the modification of organisms or the variations in species from generation to generation are open to question. The theory of natural selection so ably presented by Darwin has had its opponents, and in the recent past a considerable body of zoologists have returned to the older theory of Lamarck, but it should be fully appreciated that these discussions concern only the factors or methods of evolution, and do not show any disagreement as to the main principle itself.

Factors of Evolution

When we attempt to analyze the factors which have been operative in organic evolution, we see two quite strongly contrasted principles: one, of a tendency to variation; the other, the equally evident tendency of individuals to repeat themselves. If this repetition were perfect, if there were no variation, it is difficult to see how we could secure divergencies such as provide for the formation of new species or new groups of animals. An essential factor then lies in the cause of variation, and special effort has been directed toward attempts to discover the sources of variation. Darwin, in his theory of natural selection, assumes variation, and does not attempt to explain it, although suggesting some factors which might have some bearing in that direction. The Lamarckian theory introduced certain forces as influencing the direction of variation, especially the effect of use and disuse of organs and, admitting that variations based on this factor may be transmitted

and perpetuated, there seems to be considerable reason for recognizing it as a positive factor.

External physical conditions seem to have been effective possibly in both ways; that is, by actually changing form or structure, with possible transmission, or in connection with the selective power of the animal operating through natural selection to secure distinct modifications in a definite direction.

De Vries' contribution, the emphasis upon sudden and extended variation in particular species (**mutation**), affords for certain forms, at least, a distinct and definite means by which new forms may arise, and, while we may not by any means assume that such variations will account for all the varied forms of life, we may evidently recognize it as one method by which such variation may occur. Isolation, either geographical or physical, doubtless serves to perpetuate distinct forms or assist their divergence.

We may recognize, then, two pretty distinct series of factors: one, originating variations and including such forces as use, disuse, chemical pressure, chemical stimuli, and thermal action; and second, secondary factors which have to do simply with the preservation or perpetuation of variations produced by any of the preceding factors; and of these natural selection is perhaps the most potent, especially if connected with what we consider the forces of isolation.

Animal Industries

Animal life offers the basis for a host of most important industries and some of these are very fully utilized at the present time, —such enormous industries as the stock industry, represented in the raising of horses, cattle, sheep, and swine; or the poultry business, based on the different domestic fowls, especially the chicken, turkey, ducks, geese, and pigeons; the fishery industries, dependent on such well-known forms as the cod, salmon, herring, carp, and others; and the oyster and pearl industry. It may be considered as certain, however, that there are many most important indus-

tries in process of growth or which may be developed to a very much greater extent on forms of animal life which are now largely neglected. Among the most promising of these is the production of fur-bearing animals under some definite systematic plan of cultivation, so that the industry may be perpetuated even after the native habitats are invaded by settlement. Certainly many tracts of wild land might be made most profitable by regulating the methods of use so as not entirely to destroy the animals but to provide for their indefinite production. Such regulation will undoubtedly come for many species as settlements become extended into the wilder regions, but in the meantime there is extreme danger of the extinction of some most valuable species. The approaching extermination which has been noted for the buffalo, beaver, and some other most valuable forms should be a warning in this regard. The more systematic cultivation of the sponge, oyster, pearl mussel, fresh-water fishes, frogs, turtles, and other aquatic forms in order to utilize the many and extensive unused tracts of swamp, shallow water streams, ponds, reservoirs, etc., requires the utmost care and systematic study.

Organization for Research

The organization of zoological study provides for the acquisition of new information regarding the resources dependent upon animal life, and some of the principal ones are deserving of special mention. The Federal Government provides for several quite important bureaus of this sort. The Bureau of Fisheries is not only devoted to the study of the fishes proper, but gives attention to many forms of aquatic life, the work thus far, however, having been devoted more particularly to fishes and such fresh-water forms as may serve to assist in stocking the inland waters. The Bureau not only carries on extensive investigations of aquatic life, but undertakes many practical phases of work, such as the distribution of eggs or young fish for the stocking of various waters, the introduction of species unknown in certain localities, the develop-

ment of proper regulations for the production and perpetuation of these industries. The Biological Survey is working particularly upon the problems connected with birds and mammals, the relation of their habits to other forms of life, the problems of bird and mammal preservation. The Bureau of Animal Industry is concerned not only with studies of the live stock of the country, but practically has charge of the control of the diseases of domestic animals, and the studies in this Bureau upon such diseases as Texas fever, tuberculosis, and other forms, have marked some of the most important advances in our knowledge of these subjects. The Bureau of Entomology covers a wide field of investigations of insects which are injurious to agriculture, and also the study of such useful forms as the silkworm, fig insect, and the host of parasitic forms that control the destructive ones, and the problems connected with the introduction and spread of destructive species from foreign countries. This Bureau has to its credit some of the most important advances in economic entomology, and its work has been taken as a standard for many other countries. Aside from these sources of knowledge, there are in the different states experiment stations, which in almost all cases include departments that have to do with investigations of the animal life in their respective districts, and a great deal is being learned regarding the methods of protecting live stock against destructive forms, and the utilization of species which have had but little or no value in the past. There are also many lines of study carried on in universities, colleges, state departments, etc., which are continually adding to our knowledge concerning the resources dependent upon animals, and it is a most important matter that students of zoology should be in touch with these different sources of new information.

The publications of such organizations are in many cases available to any one interested either without cost or upon payment of very small amounts, and students in any state may, as a rule, obtain from their experiment station or from the government bureaus such publications as will be of direct service to them in connection with study upon any particular form of life.

Geological Succession in Animal Life

The occurrence of animals throughout a long period in the earth's history is abundantly shown by the fossil remains that occur in profusion in almost every system of stratified rocks.

As these stratified rocks must have been laid down in water in regular succession from below, so that where we find a series one above another we may be certain that the lowest are the oldest, it is evident that we have a positive measure by which to determine the relative age of the different fossil forms.

Since we have had occasion at times to refer to some of these extinct forms of animals, or to the occurrence of living species in past time, it will be of service in understanding the position of these various geological periods to give an outline of the geological succession as presented by geologists.

The following series is presented in Scott's *Introduction to Geology:* —

Table of Major Geological Divisions

Cenozoic Era	Quaternary Period
	Tertiary Period
Mesozoic Era	Cretaceous Period
	Jurassic Period
	Triassic Period
Paleozoic Era	Permian Period
	Carboniferous Period
	Devonian Period
	Silurian Period
	Ordovician Period
	Cambrian Period
Pre-Cambrian Eras	Algonkian Period
	Archæan Period

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